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CONTENTS.

TRACK MAINTENANCE DURING PERIODS OF BUSINESS DEPRESSION.

MANY OF OUR larger railways put into effect a policy of retrenchment under adverse business conditions. For a new railway where the amount of business which will be handled is uncertain, and where the earning power has not been demonstrated, such a policy may be a good one. Can the same be said for our old and well established railways? Many railways are absolutely sure that they are going to get the business sooner or later, and still they adopt a policy of curtailing operating expenses, many times crippling departmental organization by laying off large numbers of men.

In the maintenance of way department it is easy to see the advantage of a policy of greatest repair activity at the time of the least traffic. All maintenance work must be done between trains. When surfacing (for instance), the less the number of trains the fewer times will a temporary run-off be needed. In addition to again raising such run-offs (which is duplicated work in large part) it is frequently necessary to run back over a short stretch of track which was insufficiently tamped at the time the train was let over. If work is done when traffic is light the section foreman will be able to keep up his track with the regular section crew, insuring that, in general, the work will be thoroughly done, which is doubtful if the work is done by an extra gang.

When trains are few, the section foreman may accomplish work with a small gang which he would not attempt when traffic was heavy, and when delay to tonnage freight trains might mean a serious interruption to traffic, especially if such a train were stopped going up a steep grade.

When track is poorly maintained, there is an extra injury both to roadbed and rolling stock. A low joint gives excessive jar to the rolling stock, causes battering of the rail joints and destructive wear on the rails. That rolling stock should be kept in good repair is essential in order to get the maximum amount of service from the rolling stock itself. But it is not only on rolling stock that defective equipment produces excessive wear. Defects in tires, worn tires, loose or dragging parts may also cause unnecessary wear, and even destruction of frogs, interlocking, cattle guards, etc. Line and surface of track are also liable to be impaired by defective equipment or wrecks may result directly or indirectly.

Labor is now beginning to choose between the permanent and the temporary job, and the preference is being given to the permanent job, even at an appreciable lower rate. Fluctuations in the demand for railway labor are tending to drive labor to other fields. If the maintenance and repair forces are cut down temporarily, a great many experienced men are liable to be lost permanently. Then when business again picks up and the whole equipment is needed, a large number of men must be obtained at once. There is little chance or time for intelligent selection, and the result is that there is obtained a great number of laborers, possibly of low intelligence, unorganized and inexperienced. The labor results obtained, under such circumstances, are small, and it takes considerable time to bring such labor to any degree of efficiency. If the original force were kept the work would be done much more cheaply and in a more lasting and workmanlike manner.

The efficiency and inefficiency of labor is being given a great deal of attention at the present time. What advantage is it to a laborer to increase his efficiency if he is to be laid off on the slightest provocation? It is only reasonable to suppose that he will try and make each task last as long as possible in the fear that its completion may be the time for dismissal.

It is plainly evident that in construction there is advantage in putting work through when business conditions are poor, and when labor (a large part of which is necessarily employed temporarily) is plentiful and cheap. Better labor is obtainable in large amount, and at any time. Some of the motive power and rolling stock which would otherwise be idle and earning no interest could be used to good advantage. Many times construction costs are increased materially by the use of engines which should never leave the shop, or should be in the scrap pile. These engines are sent out because there is such a great demand for all the serviceable engines on the freight runs.

Economics of Tonnage Rating.

THE ARTICLE ON the economics of tonnage rating suggests some points in connection with the present wide discussion of "scientific management." That the method of rating the tonnage of trains for different classes of engines merely by their maximum capacity on the ruling grade may result in waste, is evident from statistics given in the article. It is apparent that there is here an application of scientific principles resulting in an appreciable saving in cost. The investigation also gave a check on the freight engineers, in that the exact work and operation to be expected from a given engine, properly handled, was obtained.

The collection of operating data and comparison with theoretical computations, gives valuable information on the efficiency of types of engines, and on variations among engines of the same type.

Many of the points discussed seem to appeal more directly to the mechanical than to the engineering department. The reason for the recent widespread interest of the civil engineering departments of railways in these questions is that much of the information obtained is of value in other problems, such as the proper spacing of automatic signals, economical grade revision, etc. Economical railway location would also imply a consideration of many of the points of economical tonnage ratings.

The latter question has been under consideration by the American Railway Engineering Association, but the committee appointed has not brought in definite recommendations, owing to the difficulty of obtaining statistics from the railways. The chairman stated in his report, March 22, 1911, that: "Authentic data with reference to operation of railways was necessary in order to proceed much further with the work as outlined;" also, "the work of this committee is vitally connected with the economic operation of railways."

Reclamation.

RECLAMATION OF SWAMP LANDS is being given wide-spread attention. The railways of the country have ever been advocates of reclamation and have usually assisted in all possible ways any operations of this nature. That the individual railways benefit we cannot deny. This is simply another case where the welfare of the railways is inseparably connected with the welfare of the nation. In order to increase railway business, it is desirable that all land be under cultivation; the same condition is desirable in order to increase the nation's wealth and the welfare of the individual. The remarkable increase in land values and in population within the last 10 to 20 years has made feasible the draining of lands which formerly were not worth the cost of reclamation.

It has been estimated that there are about 80,000,000 acres of lowlands in the United States which might be transformed into profit producing farms. The national government is the logical agent for such an immense undertaking, and all possible co-operation should be afforded by the railways and public organizations, as well as by individuals.

Illinois, Iowa, Minnesota, Wisconsin and Michigan are all considered good farming states, and yet they have over 15,000,000 acres of swamp lands.

Recently the presidents of the Missouri Pacific and of the Frisco system invited a party of government officials and lecturers to make a tour of Arkansas, Louisiana, and other states in the interest of reclamation of swamp lands. The invitation was extended to a party which was making an inspection trip on the Reclamation Special of the Illinois Central R. R.

In their telegram to secretary of the interior Fisher, Presidents Winchell and Bush, among other things, say:

"There is no movement to-day of more importance than reclamation of our swamp lands, affecting both health and prosperity, and while your party is organized we ask that you also include in your itinerary a trip over that part of railroad lines which we represent which traverse swamp lands on the west side of the Mississippi River, crossing the Mississippi River either at New Orleans or Baton Rouge as best suits your schedule, and coming north through Louisiana, Arkansas and Missouri as far as Cape Girardeau. In Southeast Missouri you can inspect extensive drainage operations which have been completed and which are in progress."

Thus it is seen that these two great systems are fully alive to the importance of the question, and are willing to afford all assistance in their power. This is the typical attitude of the progressive railways though all are not as active.

Reinforced Concrete in Railway Construction.

THE MANY ADVANTAGES of railway structures of reinforced concrete is causing a remarkable increase in this class of structures; the diversified uses to which this type of construction has been put is shown by an article on another page of this issue.

One drawback to the use of reinforced concrete is the great difficulty and cost of wrecking such a structure if circumstances necessitate it. This brings out the idea that designing must be far-sighted, in order not to necessitate replacing for a great many years, and in designing structures, wherever possible, so that additions or enlargements may be made.

A reinforced concrete building erected only four years ago is now being wrecked to make way for a larger structure. Dynamite is used to break up the concrete, and oxy-acetylene is used to cut the reinforcing bars. This process is much more expensive than that necessary in most any other kind of construction, although the oxy-acetylene flame has proven highly efficient in cutting up metals.

The effect of electrolysis on reinforced concrete structures has until recently been an open question, and is far from being settled at the present time. It has been found necessary to tear down one building on account of electrolytic corrosion. An account of the report on this building was given before the

Franklin institute by Dr. Allerton S. Cushman in which he made this statement: "The writer has himself recently been called upon to inspect and report on a full reinforced concrete structure, which cost $400,000 to build about four years ago and which has been ruined by electrolysis from escaped railway current."

That there is little danger from electrolysis in most cases is attested by the fact that out of a large number of cases investigated, this is the only one on record where the damage necessitated the wrecking of the building.

Against these disadvantages (which can probably be overcome by correct design) we have so many advantages that it is certain that the phenomenal growth of this type of structure will continue, especially in view of the fact that, in rural districts (where many railway structures are located) the danger from stray electric currents is reduced to insignificance.

Concrete in Railway Construction.

Compiled from Data Furnished by the Atlas Portland Cement Co.

CHAPTER I.

General.

While the policy of European railroad engineers always has been to build permanent structures, the necessity in the past of practising the strictest economy in the original building of many of the railroads of this country has led American engineers to exactly the opposite course, and as a result railroad structures built not many years ago were largely of timber; bridges were of the Howe truss and lattice type, trestles of pile and timber construction, and stations, roundhouses and freight sheds veritable wooden fire traps.

The increasing importance with the attendant increase of incomes of the railroads and the need for more permanent structures coupled with the improvements in iron manufacture resulted in the substitution of wrought iron structures in place of the wood, and this material in turn was replaced by steel. But it was soon found that steel was by no means perfect, since structures built of it required careful inspection and continual repairs and even then rust and gases had such a deteriorating effect that the life of a steel bridge or building would probably be not over 30 or 40 years.

In the past few years concrete construction has had a marvelous growth, and in railroad construction perhaps more than in any other branch of engineering it has been universally adopted as a building material. Not only is it replacing steel construction, but perhaps still more it has taken the place of stone and brick masonry not only for foundations but also for various structures above ground, such as retaining walls, bridges, coaling stations, signal towers, and in fact many of the smallest details.

Cost.

While the cost of concrete construction is invariably higher than wood, it is almost always considerably less than stone masonry and will not greatly, if at all, exceed steel in first cost. The maintenance costs of a concrete structure are practically negligable and it has been estimated that the elimination of painting costs alone warrants an initial expenditure of from 10 per cent to 15 per cent over the first cost of a steel structure.

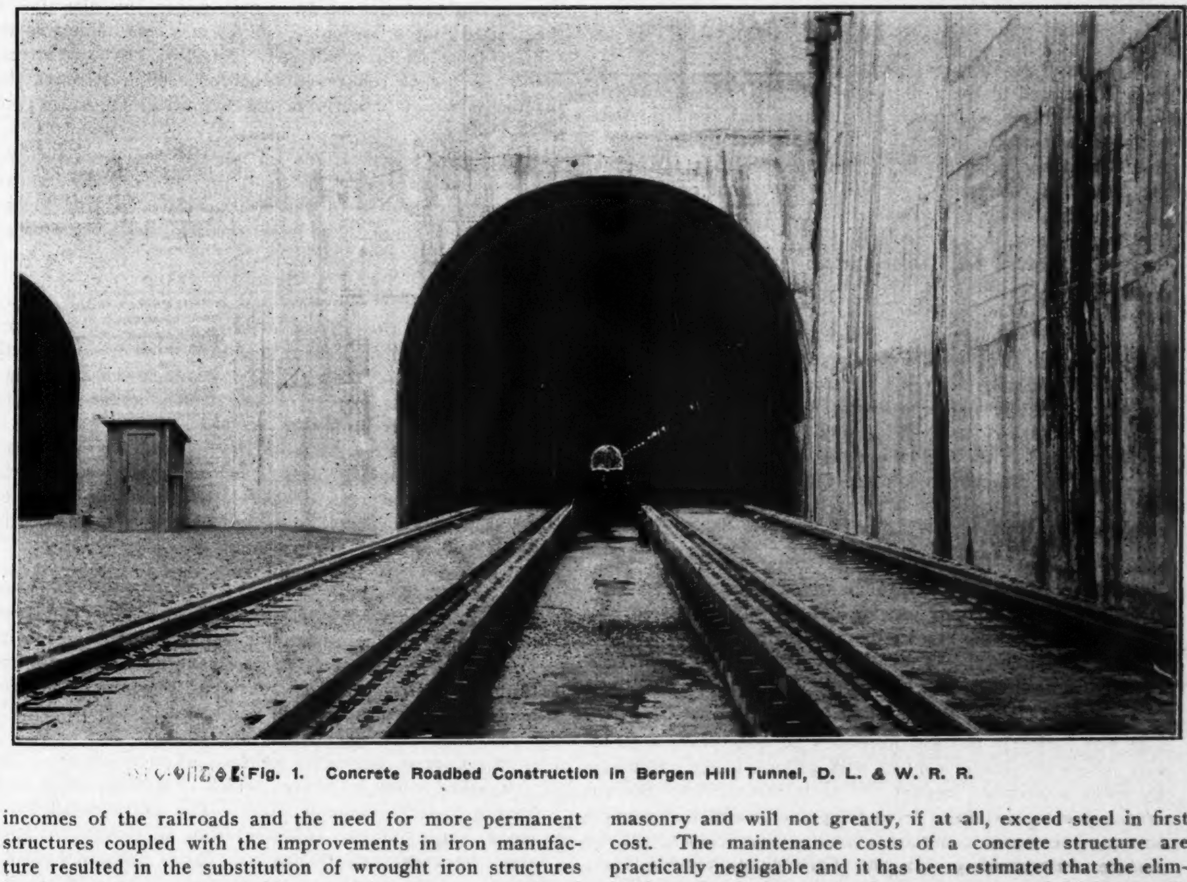


Fig. 1. Concrete Roadbed Construction in Bergen Hill Tunnel, D. L. & W. R. R.

Safety.

When well designed and properly constructed, a reinforced concrete structure will be safe for all time, since its strength

increases with age, the concrete growing harder and the bond with the steel becoming stronger. In building such a structure, it is of the utmost importance that the plans and specifications should be followed absolutely and that work should be entrusted only to men of undoubted experience in this line of construction.

Durability.

While steel and wooden structures grow weaker from rust and decay a concrete structure as stated above grows stronger with time and its life is measured by ages rather than years. In addition to its natural permanence, such a structure is proof against tornadoes, high-water, fire and earthquakes. A number of concrete buildings in San Francisco withstood the shock of the earthquake, while those around them of terra cotta brick and stone were destroyed.

Freedom From Vibration.

Concrete is especially adapted for railroad construction owing to the fact that its solidity and entire lack of joints render it free from the excessive vibrations often experienced in steel structures. In riding over a structure built of concrete it is particularly pleasing to the passenger to note the absence of the familiar roar and the lurching of the train which is so often endured in crossing a steel bridge. Only where there is direct contact, as in ties, is there danger of the jar disintegrating the concrete. In such cases either cushions of wood or earth should be provided to deaden the shock, or the concrete should be placed in large mass.

Fire Resistance.

In addition to its permanence and strength, concrete is especially suited to the construction of warehouses, terminal buildings, bridges, stations, coal pockets and similar structures on account of its undoubtable fire-resisting qualities. Actual fires and fire tests have demonstrated time and again the ability of reinforced concrete to withstand even extraordinary fires. This is a valuable asset not only for buildings and warehouses, but particularly for structures to be used for the storage of coal, since the railroads of this country have suffered in the past much inconvenience and expense through the use of inferior bins of timber or steel. The spontaneous combustion to which coal is subject when stored in great quantities not only results in the loss of the coal itself and the damaging of much valuable machinery, but also in the destruction of the bin if it is constructed either of wood or steel. As a result of the lessons taught by the recent terrible fires along the waterfront of Hoboken, the new piers designed to replace those burned down in the fire of 1904 are to be built entirely of concrete and steel construction.

Versatility of Design.

Concrete enjoys a wider range of possible use and varieties of design than any known building material. An evidence of its adaptability to the endless variety of uses in railway design is shown by the numerous classes of construction described in this article.

Water-Tightness.

It was formerly thought necessary to waterproof a structure where it came in contact with ground water. But now by using a proper amount of reinforcement to prevent cracks due to shrinkage from temperature and by properly forming the joints, concrete is used in many cases with no surface waterproofing. In the Philadelphia subway after experimenting with various methods of waterproofiing it was decided to depend entirely on the concrete itself, and in the New York subway no waterproofing is now being used above high-water level. Concrete is especially adapted for use in the construction of conduits, dams, tanks, reservoirs and other structures which, to accomplish their purpose, must be essentially water-tight.

Alterations.

Owing to the difficulty in tearing it down concrete is not suitable for a temporary structure. While radical changes in construction are not readily made, holes may be cut in walls and floors, at greater expense than in wood, but without serious difficulty.

Strengthening Old Masonry.

Concrete from its very nature is well adapted for reinforcing or strengthening and protecting old stone masonry which is being disintegrated by the action of the weather.

Foundations.

Concrete has been used for foundations in railroad construction for years; in fact, until recently this was practically the only use. With the development of design, reinforcement has been introduced which often saves much material.

CHAPTER II.

Design and Construction.

Although the use of reinforced concrete is comparatively recent, there have been sufficient tests and the theory is far enough developed to design with absolute security not only masonry structures like foundations, bridges, retaining walls, abutments and piers, but structures embodying beams and slabs, such as girders, bridges, coaling stations and power plants.

Numerous tests have been made during the last few years on almost all the details of concrete construction not only at nearly all the universities, but the Structural Materials Testing Laboratories at St. Louis under the direction of the United States Geological Survey has been taking up the subject in a scientific manner. Besides this experimental work, the use of reinforced concrete is so widespread that practice is rapidly confirming the theoretical demonstrations.

Cement.

While brief specifications for cement may be sufficiently comprehensive for work of minor importance, the standard specifications adopted by the American Society for Testing Materials* are generally adopted for important work throughout the country.

Sand.

The selection of sand for use in concrete work is quite as important as that of the cement and it should be carefully tested for all important structures. As a guide for the proper selection of the aggregates the following is quoted from the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.*

"a. Fine Aggregate consists of sand, crushed stone, or gravel screenings, passing when dry a screen having ¼-inch diameter holes. It should be preferably of silicious material, clean, coarse, free from vegetable loam or other deleterious matter.

"A gradation of the grain from fine to coarse is generally advantageous.

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand."

Broken Stone and Gravel.

"b. Coarse Aggregate consists of inert material, such as crushed stone, or gravel, which is retained on a screen having ¼-inch diameter holes. The particles should be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat or elongated particles

*These may be obtained by addressing The Atlas Portland Cement Company.

*Affiliated Committees of American Society of Civil Engineers, American Society of Testing Materials, American Railway Engineering and Maintenance of Way Association, Association of American Portland Cement Manufacturers.

should be excluded from important structures. A gradation of size of the particles is generally advantageous.

"The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3-inch ring. For reinforced members a size to pass a 1-inch ring, or a smaller size, may be used.

"Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fireproofing.

"Where cinder concrete is permissible the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes."

Steel.

There is frequently a question as to the use of high or low carbon steel. High carbon steel is very apt to be brittle unless it is made so as to pass severe tests, when it can be depended upon. It is generally economical to use ordinary medium steel unless perhaps for temperature reinforcement, when steel with high elastic limit and deformed section is especially good.

For ordinary uses, deformed bars, that is, bars with irregular sections, while satisfactory and in some cases better than ordinary round bars, are usually not absolutely necessary.

Proportions.

In such a broad field of construction as is found in railroad work, it is impossible to give any general recommendations as to the proper proportions to use, as this depends so much on the structure itself. For any specific structure, the reader is referred to the proportions adopted in the construction of similar structures described in the text.

The standard method for measuring parts is to assume one part as equal to 4 bags of cement, or one barrel. In measuring the sand and stone a barrel is assumed as 3.8 cubic feet. The actual volume of a cement barrel averages about 3.5 cubic feet, but the 3.8 cubic feet has been adopted generally in practice as corresponding to a weight of 100 pounds of cement to the cubic foot, which is that of the cement partially compacted; thus proportions 1:2:4 means one barrel (or 4 bags) Portland cement, 7.6 cubic feet sand measured loose and 15.2 cubic feet of broken stone or gravel measured loose.

Mixing.*

"The ingredients of concrete should be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

"(a) Measuring Ingredients. Methods of measurements of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

"(b) Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

"(c) Hand Mixing. When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color."

*From Joint Committee's recommendations.

Consistency.

The required consistency varies with the class of work. Concrete is strongest when not too wet, but of a medium, jelly-like consistency. For reinforced concrete it must be softer, so that it can just flow sluggishly around the steel and into the forms. At the same time it should be stiff enough to be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

Placing.*

"(a) Methods. Concrete after the addition of water to the mix should be handled rapidly, and in as small masses as practicable from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is liable to occur between mixing and final placing.

"The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

"In depositing the concrete under water, special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

"Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

"When work is resumed, concrete previously placed should be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

"The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

"(b) Freezing Weather. The concrete for reinforced structures should not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

"(c) Rubble Concrete. Where the concrete is to be deposited in massive work its value may be improved and its cost materially reduced through the use of clean stones thoroughly embedded in the concrete as near together as is possible and still entirely surrounded by the concrete."

Joints.

In walls of any considerable length it is necessary to provide against shrinkage and temperature cracks. The general practice for walls of plain concrete is to place contraction joints at intervals of from 30 to 50 feet, but in many instances this has not been sufficient and the author recommends a spacing from 20 to 30 feet. Walls can be built with no joints by providing sufficient reinforcement to so distribute the temperature stresses that the cracks will be very minute and scarcely noticeable on close inspection.

Surfaces.

The proper treatment to give a pleasing appearance to exposed surfaces is one of the most difficult problems in concrete construction and a number of different methods have been employed, all of which are illustrated by different structures described in the text.

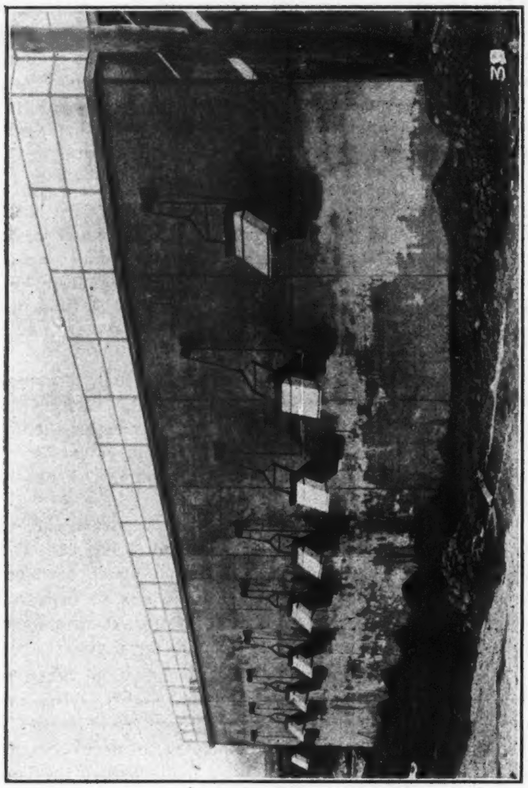


Fig. 4. D. L. & W. R. R. Retail Coal Pocket, Murray Hill, N. J.

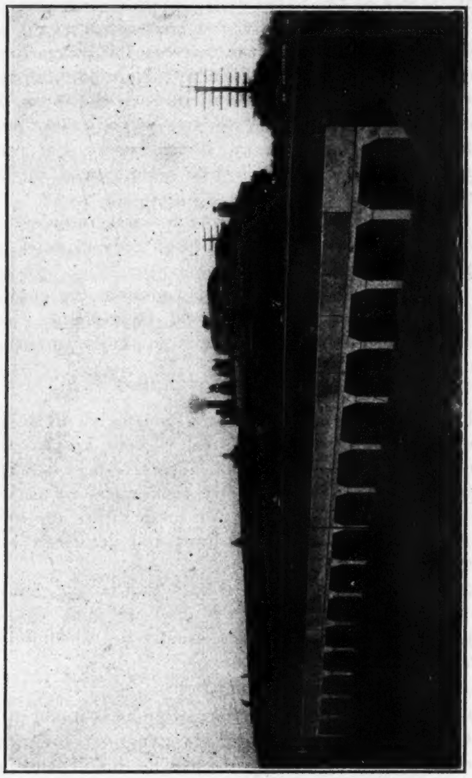


Fig. 5. Crushed Stone Handling Trestle, Springfield, Mass.

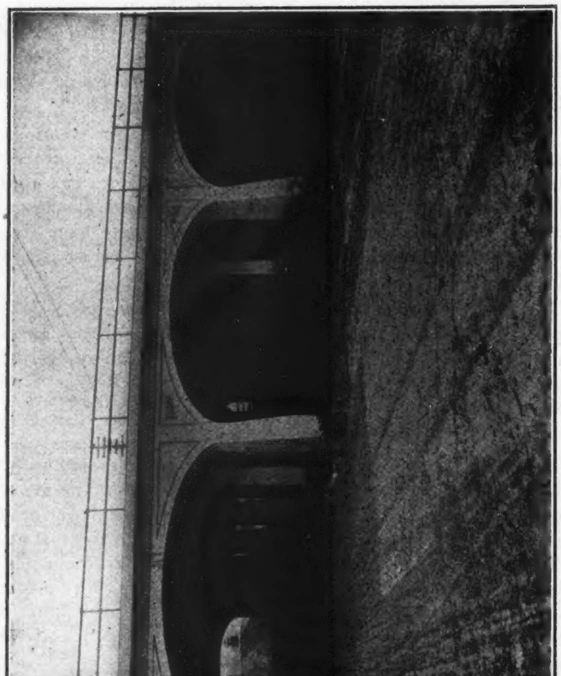


Fig. 2. Winnipeg Viaduct, Canadian Pacific Ry.

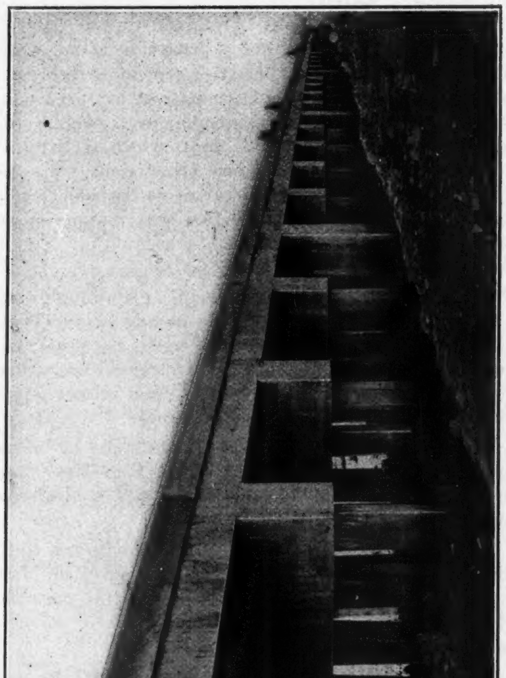


Fig. 3. Pile Trestle over Salt River, C. B. & Q. R. R.

Forms.*

"Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight to prevent the leakage of mortar.

"The time for the removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete. Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

"So many conditions affect the hardening of concrete that the proper time for the removal of the forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavorable."

Waterproofing.

While many expedients have been used to render concrete impervious to water, experience has shown that, where the concrete is proportionated to realize the greatest practicable density and is mixed to a rather wet consistency, it is sufficiently impervious itself, for ordinary purposes, without further treatment. The proportions generally used to resist the percolation of water range from 1:1:2 to 1:2:4, the latter being the most common mixture. Sometimes, where the mass of the concrete is considerable, or where the walls are thin, a material like hydrated lime or dry powdered clay may be efficient for void filling and permit the use of leaner proportions. In subways, long retaining walls, and reservoirs, cracks can be prevented by horizontal reinforcement properly proportioned and located. In any case, for water-tight work the concrete should be mixed wet enough to entirely surround the reinforcing metal and flow against the forms.

Asphaltic or coal tar preparations applied either as a mastic or with paper or felt are used to good advantage where it is deemed unadvisable to rely upon the natural imperviousness of the concrete itself.

Design of Plain Concrete.

In the design of plain concrete, sections should be so proportioned as to avoid tensile stresses, and while this may be accomplished in the case of rectangular shapes by keeping the line of pressure within the middle third of the section, in very large structures a more exact analysis may be required.

Inasmuch as structures of massive concrete are able to resist any unbalanced later forces by reason of their weight, a relatively cheap and weak concrete is often suitable for such conditions.

Bending Moments.

In reinforced concrete design as much variation may be had in the results by the selection of the bending moments as in the choosing of working stresses. If the members are continuous beams or slabs, special care must be taken in the design at the supports, since there is much and frequently more stress there than at the middle of the span. It is not safe practice to design a continuous beam in the center as though it was simply supported and then pay no attention to the design over the supports.

Good practice and the recommendations also of the Joint Committee on Concrete and Reinforced Concrete (1909) sanction the following formulas for bending moments:

Let $P =$ concentrated load in pounds.
$w =$ unit distributed load in pounds per square foot (including the dead load).
$l =$ length of member between centers of support in feet.
$M =$ bending moment in foot pounds.

To transform the bending moment to inch pounds, multiply by 12.

For beams and slabs simply supported at the end and not continuous:

$$M = \tfrac{1}{8}\, wl^2 \text{ for distributing load} \qquad (1)$$

and

$$M = \tfrac{1}{8}\, wl^2 + \tfrac{1}{4}\, Pl \text{ for distributed load plus a load concentrated at the center} \qquad (2)$$

For beams and slabs truly continuous and thoroughly reinforced over the supports:

$$M = 1/12\ wl^2 \text{ at the center of the member} \qquad (3)$$

$$\text{and} -M = 1/12\ wl^2 \text{ at the ends of the member} \qquad (4)$$

For beams and slabs partially continuous, as end spans, or for continuous members of 2 or 3 spans:

$$M = 1/10\ wl^2 \text{ at the center of the member.} \qquad (5)$$

The negative bending moments which exist at the supports must be provided for by steel rods carried over the top of the support for tension and by a sufficient amount of concrete at the bottom of the beam near the support to take the compression.

If a part of the tension rods are bent up on an incline from about one-quarter points in the beam so as to pass horizontally through the top of the beam at the supports, they must extend over the supports for a sufficient distance to transmit the compressive stress there, or must be firmly connected with corresponding rods in the adjacent bay. The total steel in the top must be sufficient to resist the tension due to negative moment, and the concrete and steel in the bottom next to the support, sufficient to resist the compression.

For cantilever beams, that is, beams with one end fixed and the other end free, where the maximum bending moment is at the point of the support and the tension is in the top of the beam, the following formulas hold:

With a uniformly distributed load over the length of the beam:

$$-M = \tfrac{1}{2}\, wl^2 \text{ at the support.}$$

If also a live load is concentrated at the end

$$-M = Pl + \tfrac{1}{2}\, wl^2$$

Design of Reinforced Concrete.

In designing a reinforced concrete member it is not sufficient to simply determine the amount of steel required to resist the tensile stresses, but a most careful analysis must be made of all parts of the structure.

The correct design of reinforced concrete beams and girders involves the following studies:

(1) The bending moments due to the live and dead loads.

(2) Dimensions of beams which will prevent an excessive compression of the concrete in the top and which will give the depth and width which is otherwise most economical.

(3) Number and size of rods to sustain tension in the bottom of the beam.

(4) Shear or diagonal tension in the concrete.

(5) Value of bent-up rods to resist shear or diagonal tension.

(6) Stirrups to supplement the bent-up rods in assisting to resist the shear or diagonal tension.

(7) Steel over the supports to take the tension due to negative bending moment.

(8) Concrete in compression at the bottom of the beam near the supports due to negative bending moment.

(9) Length of rods to prevent slipping.

(10) End connections at wall.

Working Stresses.

The working stresses for static loads given below follow the recommendations of the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.

"General Assumptions. The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.

"In selecting the permissible working stress to be allowed on concrete, we should be guided by the working stresses usually allowed for other materials of construction, so that all

*From Joint Committee's Recommendations.

structures of the same class, but composed of different materials, may have approximately the same degree of safety.

"The stresses for concrete are proposed for concrete composed of one part Portland cement and six parts aggregate, capable of developing an average compressive strength of 2,000 pounds per square inch at twenty-eight days, when tested in cylinders 8 inches in diameter and 16 inches long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors recommended with relation to this strength, it is to be borne in mind that the strength at twenty-eight days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes in which the material of the aggregate is inferior, all stresses should be proportionally reduced, and similar reduction should be made when leaner mixes are to be employed. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

"Diagonal Tension. In beams where diagonal tension is taken by concrete, the vertical shearing stresses should not exceed

2 per cent of compressive strength at twenty-eight days, or 40 pounds per square inch for 2,000 pound concrete.

"Bond for Plain Bars. Bonding stress between concrete and plain reinforcing bars,

4 per cent of compressive strength at twenty-eight days, or 80 pounds per square inch for 2,000 pound concrete. For drawn wire,

2 per cent, or 40 pounds on 2,000 pound concrete.

"Bond for Deformed Bars. Bonding stress between concrete and deformed bars may be assumed to vary with the character of the bar from

5 per cent to 7½ per cent of the compressive strength of the concrete at twenty-eight days or from

100 to 154 pounds per square inch for 2,000 pound concrete.

"Reinforcement. The tensile stress in steel should not exceed 16,000 pounds per square inch. The compressive stress in reinforcing steel should not exceed 16,000 pounds per square inch, or fifteen times the working compressive stress in the concrete.

"Modulus of Elasticity. It is recommended that in all computations the modulus be assumed as 1/15 that of steel; that is, that a ratio of fifteen be employed.

"Bearing.† For compressioin on surface of concrete larger than loaded area,

32.5 per cent of comparative strength at twenty-eight days or 650 pounds per square inch on 2,000 pound concrete.

"Plain Columns. Plain columns or piers whose length does not exceed twelve diameters.

22½ per cent of compressive strength at twenty-eight days, or 450 pounds per square inch on 2,000 pound concrete.

"Reinforced Columns. (a) Columns with longitudinal reinforcement only, the unit stress recommended for plain columns.

(b) Columns with reinforcement of bands or hoops, as specified below, stresses 20 per cent higher than given for (a).

(c) Columns with not less than 1 per cent and not more than 4 per cent of longitudinal bars and with bands or hoops, stresses 45 per cent higher than given for (a).

(d) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent higher than given for (a)."

"In all cases, in addition to the stress borne by the concrete given above, longitudinal reinforcement is assumed to carry its proportion of stress in accordance with the ratio of its elasticity to concrete. For example, with a working stress in concrete of 450 pounds per square inch, the longitudinal reinforcement may be assumed to carry 15x450=6,750 pounds per square inch.

"The hoops or bands are not to be counted upon directly as adding to the strength of the column.

"Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

"Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent of the volume of the column enclosed. The clear spacing of such bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

"Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

"Compression in Extreme Fiber. For extreme fiber stress of beams calculated for constant modulus of elasticity.

32.5 per cent of the compressive strength at twenty-eight days, or 650 pounds per square inch for 2,000 pound concrete.

"Adjacent to the support of continuous beams, stresses 15 per cent greater may be allowed.

"Shear. Pure shearing stresses uncombined with compression or tension. 6 per cent of compressive strength at twenty-eight days, or 120 pounds per square inch for 2,000 pound concrete."

CHAPTER III.

Bridges.

One of the most important applications of concrete to railroad construction is in the building of bridges. By the intelligent use of reinforced concrete, bridges are being designed which are superior to similar steel, masonry or wooden structures from an artistic, structural and economic standpoint.

While the life of a wooden bridge is about 9 years and of a steel bridge probably not over 30 to 40 years, and even then with a continual outlay for repairs and painting in addition to careful inspection, a concrete bridge will last almost indefinitely and with practically no maintenance. In addition to its natural pemanence, such a bridge is proof against tornadoes, high water and fire.

Steel and wooden bridges grow weaker from rust and decay and in a few years the day comes when the bridge of decreasing strength is overloaded by the increasing weight of rolling stock and requires either strengthening or replacing. Concrete bridges on the other hand grow stronger with age and probably in as rapidly an increasing ratio as the increase in traffic.

A concrete bridge is free from the excessive vibrations and from disagreeable noise often experienced in steel bridges. Track is easily maintained on such a structure, since the ordinary track ties and ballast take the place of more expensive bridge ties of a steel structure.

In the construction of a concrete bridge there is no obstruction of traffic from swinging booms as is the case when setting stone of large dimensions in masonry bridges, nor so much difficulty in securing the necessary skilled labor during times when the building trades are active. The ma-

†For beams and girders built into pockets in concrete walls the lower compressive stress of 450 pounds per square inch should not be exceeded.

terials used can generally be obtained in the immediate vicinity of the bridge site.

The cost of a reinforced concrete bridge in almost all cases will be considerably less than that of a stone masonry structure and will not greatly, if at all, exceed that of a steel bridge, when the cost of piers and abutments is included in the comparison. Even when the cost of the steel is less, the difference is more than counteracted by the practically negligible maintenance costs of the concrete structure.

Arch Bridges.

While arch bridges may be constructed of either plain or reinforced concrete, the latter type is usually the most satsfactory, as the steel reinforcement not only permits the use of less material, but it also adds to the safety against settlements of foundations or centerings, and temperature stresses. The Wallkill River bridge shown in Fig. 7 is an interesting example of plain concrete construction, while the Jackson Street arch, shown in Fig. 8, is one of the types of reinforced arch bridges.

Arches are classified in various ways, but the most simple classification is in reference to the method of the construction of the spandrels, or spaces above the upper surface of the arch ring and below the road-bed level. These spaces are either filled in solid with loose filling or are left open by skeleton spandrel construction consisting of slabs and beams supported on columns or cross-walls resting on the arch ring.

Solid Filled Spandrels. This type of construction is generally employed for arches of spans under 100 feet. While the solid-filled spandrels usually consist of an embankment of earth, sand or cinders enclosed between solid spandrel walls having the common trapezoidal retaining-wall section, or between reinforced spandrel walls, sometimes a filling of very lean concrete is used in place of the loose material, when the spandrel become an integral part of the filling. The loose filling between spandrel walls is deposited in thin layers and thoroughly tamped by ramming, rolling or flooding it in with water.

The Jackson Street arch is an example of the solid fill spandrel type of construction.

Skeleton Spandrels Construction. For spans of about 100 feet or over the skeleton spandrel construction is, on account of its reduced weight and cost, found most advantageous.

In addition to the advantage resulting from a reduction of the load on the main arch ring and foundations this type of construction when well handled furnishes an opportunity to introduce architectural effects of great beauty. By doing away with the long and heavy solid spandrel walls the trouble with temperature strains is greatly lessened in this type of construction.

The Paulins Kill Viaduct is an example of skeleton spandrel construction.

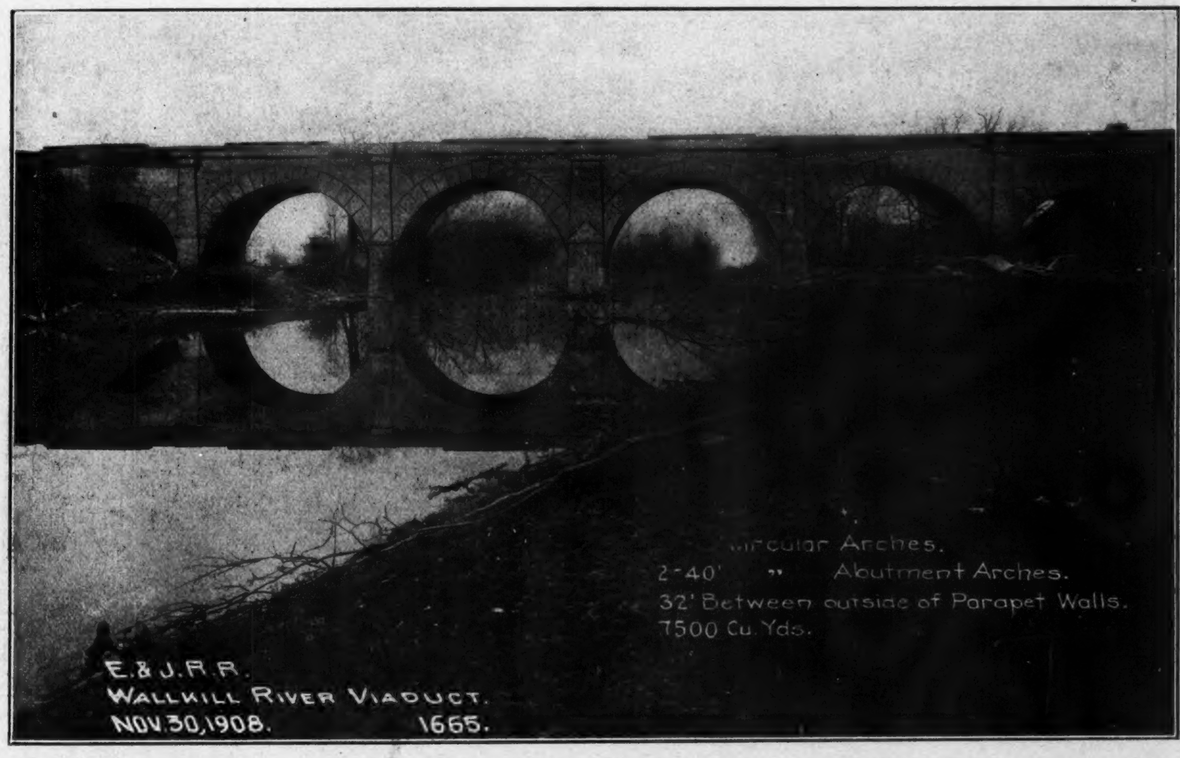


Fig. 7. Wallkill River Viaduct, Erie & Jersey R. R.

Another form of skeleton spandrel construction, an example of which is found in the Connecticut Avenue Bridge, Washington, D. C., consists of hollow spandrels with curtain walls forming a cellular spandrel construction in which the roadway is carried on a system of braced columns and beams enclosed by thin curtain walls on each side of the bridge.

Expansion Joints. To provide for the action of temperature strains, expansion joints are generally constructed in the spandrels where they meet the abutments and usually also at one or more points between the abutments and crown of the arch. Some engineers place a vertical expansion joint over each springing line and at a point about 10 feet each side of the crown. These joints which cut the spandrels vertically from the coping of the parapet wall to the arch ring, are either constructed as mere planes of weakness in the concrete or as actual joints filled with one or more layers of felt, corrugated paper or some other partially elastic material.

Another method which is sometimes adopted is to entirely omit the expansion joints and resist the temperature strains by providing sufficient reinforcing metal throughout the structure.

Waterproofing. The top of the arch and the lower parts of the spandrel walls are usually waterproofed in order to facilitate drainage and keep accumulated water from penetrating the arch rings.

Jackson Street Arch, C. R. R. of N. J. This bridge consists of a reinforced concrete arch of 54 ft. 3 inch clear span with axis on a skew of 22° 2' with the axis of the street. The photograph in Fig. 8 shows the finished arch.

The abutments and wing walls rest on 10-inch piles, the last three rows in each abutment being driven with a batter to correspond with the inclination of the line of pressure. These piles were cut off below water level, which is about 10.87 feet below the surface of the street, and a bed of broken stone 3 feet thick was rammed around them to within 6 inches of the tops where the concrete work started.

With the exception of an open expansion joint, like a vertical tongue and groove, between the ends of the abutments and the ends of the wing walls the bridge was constructed as a monolith. For the arch ring the concrete was mixed in the proportions of 1 part Atlas Portland cement, 2 parts sand and 4 parts 1-inch screened broken stone, while for the abutments and wing walls the proportion was 1:3:6 with 1½-inch stone and for the spandrel walls 1:3:5, with 1-inch stone.

The main reinforcing for the arch consists of 1¼-inch curved round rods in both intrados and extrados placed about four inches from the upper and lower surfaces. In the intrados they are spaced 12 inches apart at the springing line and extend 5 feet past the center, thus giving a spacing of 6 inches for 32 feet at the crown. In the extrados they are 12 inches apart at the abutments and carry 2½ feet beyond the center line, thus giving a 5 foot lap for bond. At the haunches auxiliary rods about 26 feet long are placed in all the spaces between the main rods. Above and below both the intrados and extrados rods, horizontal transverse ¾-inch rods are spaced 24 inches apart and extend the full length of the arch.

In designing the bridge the stress in the arch ring was computed by the graphical method of Prof. W. A. Cain, the live load assumed being the standard loading of the Central Railroad of New Jersey or 700 pounds per square foot of surface while the dead load was figured as follows: Rails, ties, ballast, 140 pounds per square foot of surface; filling, 100 pounds per cubic foot, and concrete, 160 pounds per cubic foot. Including temperature stresses the maximum stress in the concrete was 600 pounds per square inch compression and 50 pounds per square inch shear, while the maximum stress in the steel was 18,000 pounds per square inch in tension and 5,000 pounds per square inch in compression, the latter value being fixed, of course, by the permissible stress in the concrete times the ratio of elasticity of steel to concrete.

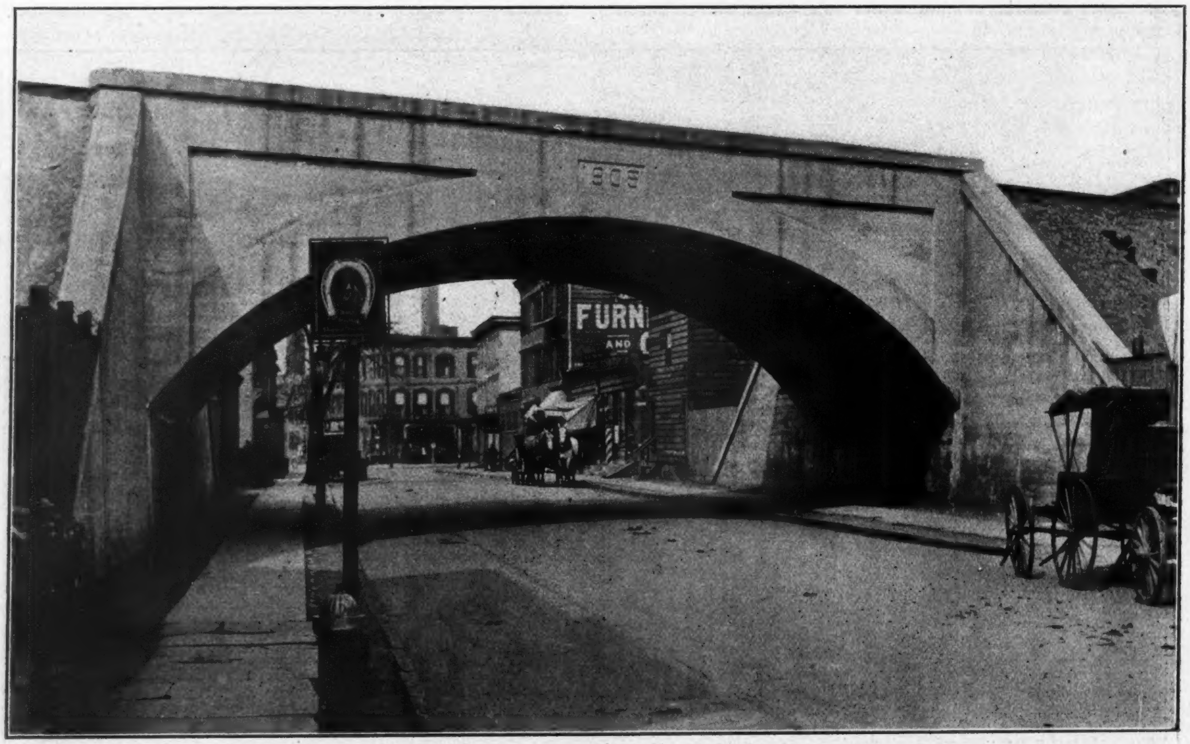


Fig. 8. Jackson St. Arch on the C. R. R. of N. J. at Newark, N. J.

The arch forms were assembled on the ground, and after the abutments were well under way they were swung into place from an erection car on the temporary trestle. During the construction of the bridge, railroad traffic was maintained uninteruptedly on temporary trestles on either side of the bridge. The concrete in the abutments and the filling behind them was carried to a point about 2 feet above the spring line of the arch, when the arch ring was put in at one operation, concreting commencing simultaneously at the springing lines of both abutments.

The concrete was mixed in a 1 cubic yard Ransome mixer on one side and a 1 cubic yard Smith mixer on the other, and was deposited from ordinary iron wheelbarrows.

With the exception of the tops of the spandrel and wing walls, which were finished with a 1-inch trowelled surface of cement mortar applied simultaneously with the last course

of concrete, the finish of the concrete was obtained by simply spading back the concrete from the forms.

The upper surface of the arch is waterproofed with four coats of Hydrex felt mopped on with Hydrex compound applied hot, and the backfill is drained from the ends of the abutments by two 6-inch cast-iron pipes connecting with the city sewer in the center of the street as shown.

The bridge was designed by the engineering department of the railroad. Mr. J. O. Osgood, chief engineer, and was constructed under their supervision in the spring of 1904 by Holmes and Coogan of Jersey City.

Paulins Kill Viaduct, D., L. & W. R. R. This bridge is approximately 1,100 feet long and 115 feet high and consists of five 120-ft. and two 100-ft. reinforced arches with skeleton spandrel arches supporting the track.

The design of the abutments furnished a rather novel and economical feature inasmuch as they are composed of three longitudinal reinforced walls carrying a reinforced slab which supports the track and ballast. This skeleton construction allows the embankment to take its natural slope between the walls as well as on the outside of them, and by thus balancing the earth pressure does away with the bulky section which would have been necessary had they been designed as retaining walls.

With the exception of the copings and ornamental railings, which are of 1:2:4 proportions, the concrete throughout the structure is mixed in the proportions of 1 part cement, 3 parts sand and 5 parts broken stone. In the abutments and piers for the arches and foundations below the ground line, large quarry stones are bedded in the concrete so as to form a rubble concrete and reduce the cost of materials.

In designing the viaduct a ratio of elasticity of steel to concrete of 15 was assumed and the concrete was figured at 600 pounds per square inch safe working fiber stress, 500 pounds per square inch direct compression and 50 pounds per square inch shear, while the steel was given a working tensile stress of 16,000 pounds per square inch.

The structure was designed by the engineering department of the Delaware, Lackawanna & Western Railroad under the supervision of Mr. Lincoln Bush, chief engineer, with Mr. B. H. Davis, assistant engineer in charge of masonry design, and Mr. F. L. Wheaton, engineer of construction, in charge of work in the field.

Wallkill River Viaduct, E. & T. R. R. This is a very heavy unreinforced concrete bridge 388 feet long, having a width of 32 feet between outside of parapet walls, and consists of four 60-ft. and two 40-ft. circular arches. The photograph, Fig. 7, is of the finished structure.

The bridge, which contains 7,500 cubic yards of concrete, was designed by the engineering department of the Erie Railroad under the supervision of Mr. F. L. Stuart, chief engineer, and was built by the Lathrop, Shea & Henwood Company, of Scranton, Pa.

Girder Bridges.

When constructed of concrete, girder bridges are designed either as entire reinforced concrete structures or as a combination of structural steel and reinforced concrete. In the latter case the main girders and cross beams are generally composed of structural shapes encased in concete with the floor slabs of reinforced concrete. An example of the former type, which contains a number of advanced and novel features, is described below, while the First Avenue viaduct, described on a following page, is an interesting example of the latter type.

In designing reinforced concrete girder bridges, care should be taken to see that there is sufficient concrete and steel provided for shearing stresses, as with short spans and heavy loads this will be found in many cases to be the determining factor.

Track Elevation Work, Chicago, Ill., C., B. & Q. R. R. In connection with the track elevation work on the Chicago, Burlington & Quincy Railroad between Canal street and Blue Isalnd avenue, Chicago, there are a number of reinforced concrete girder bridges. These bridges are notable because of their extremely large size and capacity, and for their methods of construction. The essential features of design and construction of a typical bridge consist of reinforced concrete columns and cross girders cast in place and carrying reinforced deck slabs which were moulded in sections away from the bridge site and when properly cured were transported on flat cars and set in place by a wrecking crane. After being thoroughly waterproofed the ballast and track was laid directly on these slabs.

The columns and cross girders are composed of concrete mixed in the proportions of one part cement to four parts pit-run gravel. The columns are reinforced with four 3½ by 3½ by ½ inch angles hooped spirally with high carbon steel wire. The girders and slabs are reinforced with corrugated bars.

The slabs were built along both sides of a switch track in one of the railroad yards near the city limits and after curing ninety-days were picked up by a locomotive crane and placed on flat cars and hauled to a convenient storage place where they were piled three high until required at the bridge site.

Each slab was built in a separate form and after being cast was wet thoroughly every evening for two weeks. The slabs were made with the ends and sides battered so as to have a clearance of ¼ inch between them at the bottom and 1 inch at the top on both sides and both ends. These spaces were filled with waterproofing, thus making the whole bridge floor water tight. A mixture of one part cement to four parts gravel was used in their construction. The slabs for the long spans contain approximately 19.2 cubic yards of concrete and weigh 36 tons each. In handling and setting the slabs, a 100-ton locomotive crane equipped with a special toggle frame was used.

The work was designed and constructed by the engineering department of the railroad under the supervision of Mr. C. H. Cartlidge, bridge engineer.

Trestles.

Reinforced concrete is being used for trestles of every class. In the majority of cases these are conservative and safe, but a few of the designs along the lines commonly employed in steel construction with very high bents are considered by many conservative engineers to be extreme. In structures of this type the utmost caution should be employed in the mechanics of design to see that all parts are symmetrical, that the column design is conservative and that proper provision is made for temperature stresses.

While the cost of a reinforced trestle is greater than that of a timber structure, this difference is often more than offset by the temporary character and the danger from conflagration of the latter type. As compared to steel construction, reinforced concrete is generally cheaper and possesses the additional advantage of being free from constant inspection, painting and general maintenance.

A number of very long and high trestles have been constructed during the past few years of reinforced concrete, one of the largest being the Richmond & Chesapeake Bay viaduct described below. The Chicago, Burlington & Quincy Railroad are changing over all the wooden pile trestles on their line to similar reinforced concrete structures.

Richmond Viaduct of the Richmond & Chesapeake Bay Railway.—The Richmond & Chesapeake Bay Electric Railway enters Richmond over a reinforced concrete viaduct 2,800 feet long, ranging in height from 18 feet at either end to 70 feet at its highest point. A riveted steel girder viaduct was first contemplated, but was rejected on account of the high initial cost and cost of maintenance, as well as the diffi-

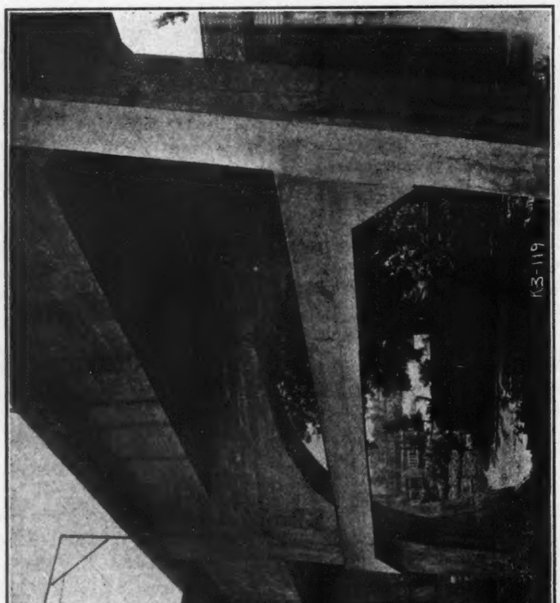


Fig. 9. Richmond Viaduct, View at Point of Curve.

Fig. 10. View Underneath Richmond Viaduct.

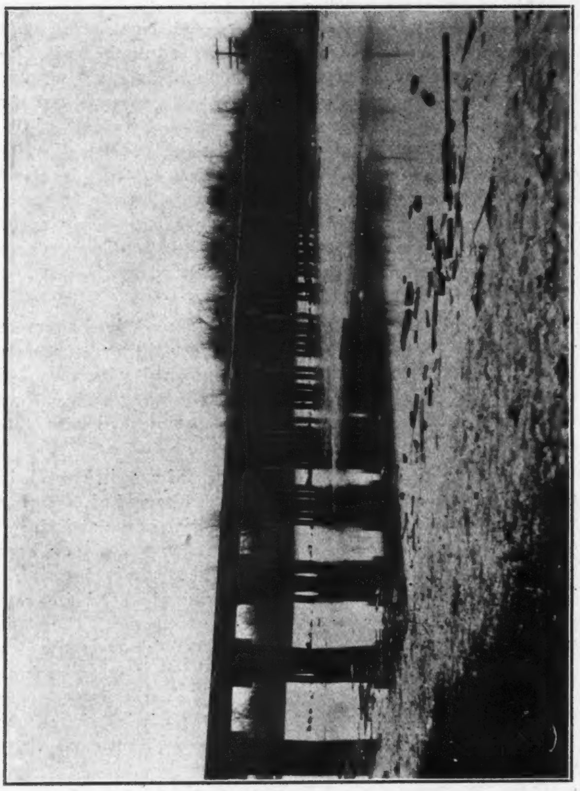


Fig. 11. Concrete Pile Trestle, C., B. & Q. R. R.

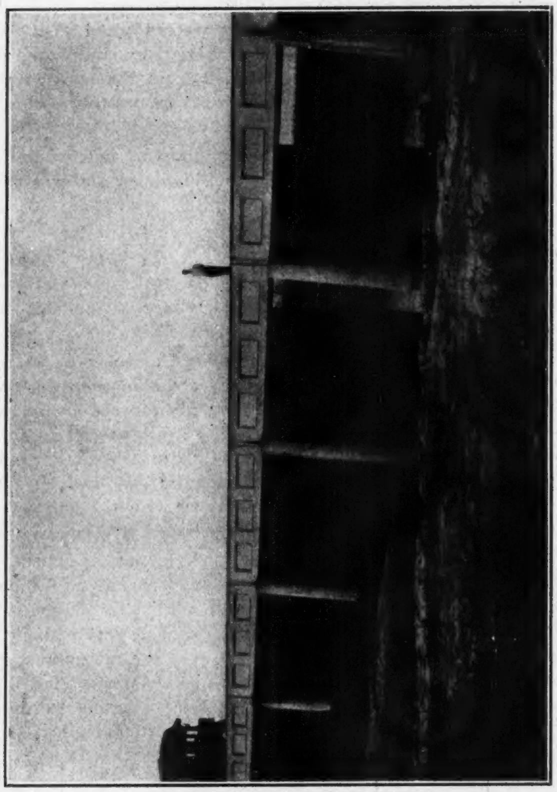


Fig. 12. C., B. & Q. R. R. Concrete Pier Trestle.

culty of double tracking such a structure should it become necessary. A wooden trestle was then planned, and some of the timber ordered and partially delivered, when considerations of fire protection as well as the necessarily temporary character of wood construction persuaded the company to adopt a reinforced concrete structure.

Bids for the design of such a structure were then called for, the rairoad company submitting only the general location, profile and prescribed loads. Under these conditions the design of the New York branch of the Trussed Concrete Steel Company, Mr. B. J. Greenhood, engineer, was accepted and the contract for the construction of the viaduct awarded to Mr. John T. Wilson, of Richmond, Va.

The viaduct was designed to carry a 75-ton car, 54 ft. long on four-wheeled trucks placed 33 ft. apart, each truck consisting of two axles 7 ft. on centers. In computing the sizes of the various members it was assumed that the viaduct should carry its dead load and the entire live load plus 50 per cent of the live load for impact. The longitudinal thrust due to the braking of trains was assumed as 20 per cent of the live load. At the curves, overturning moments were allowed for at the rate of 2 per cent for each degree of curvature. Wind pressure was figured at 30 pounds per square foot on the surface of train and viaduct.

For the superstructure, it was decided to use concrete mixed in the proportions of 1 part Atlas Portland Cement, 2 parts granite dust and 4 parts ¾-inch crushed granite, and in the footings a 1:2½:5 mixture of the same materials. The columns were designed for a compressive stress of 500 pounds per square inch on the concrete and 6,000 pounds per square inch on the longitudinal reinforcing steel. In designing the girders, continuous beam action was assumed and the concrete was figured at 600 pounds per square inch extreme fiber stress and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch. In proportioning the footings, which bear on either hard clay or compact gravel, a bearing value of 3 tons per square foot was figured on for all possible stresses including future double tracking. Kahn trussed bars were used as reinforcing for the entire structure.

The viaduct is composed of a system of girders of rectangular cross section varying in span from 23 to 68 feet supported by a series of interbraced and battered bents varying from 14 to 70 feet in height.

As will be noted by the photograph in Fig 10, the diagonal bracing which is generally seen on structural steel towers is replaced by transverse and longitudinal struts, the intention being to design all joints and all members so that they will have the rigidity to withstand bending. Provision has been made for double tracking the viaduct, when traffic warrants such an extension, by building the footings for all bents over 20 feet in height, with on offset column base to which new columns can be attached and by leaving cored holes in the girders for connecting the new work.

Expansion joints have been provided where the short girders rest on the column brackets, at intervals of about 200 feet, consisting of a grooved steel plate on top of the bent, on which a planed steel plate on the bottom of the girder slides; together with steel toggle connections at the upper part of the girder which prevent any tendency to turn the girder. An idea of the massive proportions of the trestle can be obtained by a study of the photographs in Fig. 9 and Fig. 10.

The track consists of 80-pound rails spiked to 8 x 8 inch cross ties on 12 inches centers which are notched 1½ inch over and bolted to 6x12 inch sleepers embedded in and attached to the concrete girders by means of anchor bolts. On the curves, heavier sleepers are used under the outside rail in order to gain the necessary outer elevation.

The guard rail is made of 8x10 inch hard pine notched 2 inches between the ties. By extending every fifth tie four feet beyond the concrete girder and covering this extended tie with planking, a footway 40 inches wide is provided. In a similar manner the poles for carrying the trolley wires are supported. Work on the structure was started in the spring and finished in the fall of 1906.

In the construction of the viaduct, one mixing plant, transferable from one place to another, consisting of one No. 2½ rotary mixer, hoisting engine, elevator, buckets, etc., was used. After the erection of the forms the columns and struts up to the bottom of the girders were poured at one continuous operation. The column forms were built in three sides forming a U-shape, and the fourth side built up in sections as the concrete was poured. The girders and floors were also put in at one operation.

The forms were made of 2-inch lumber dressed on one side, supported by falsework consisting of a 4 by 4 inch and 6 by 6 inch timbers. The girder sides were removed at the end of a week while the remaining forms and supporting falsework were left in place for at least thirty days. After the removal of the forms the entire surface of the viaduct was given a finish of sand and cement applied with a brush.

Concrete Pile Trestles, C., B. & Q. R. R.—These trestles, which replace similar wooden structures, possess a number of features comparatively new to the field of concrete construction. In general, the construction consists of six-pile bents spaced 14, 15 or 16 feet center to center, and with an average height of 10 feet.

Two types of piles are used, namely, rectangular cast piles and Chenoweth rolled piles. The cast or molded rectangular piles are made in lengths up to 30 feet, and are 16 inches square at the top with 4-inch chamfers. The reinforcement consists of eight ½-inch bars wired to a spiral coil of wire of varying pitch. The Chenoweth rolled pile is circular in section, 16 inches in diameter, and is reinforced with ½-inch corrugated bars wound spirally with a ½-inch mesh No. 16 wire netting. The piles are driven vertically by an ordinary railroad pile driver with a 3,000-pound hammer, with cushioned cap, falling 24 feet. The piles are capped by deep reinforced concrete cross girders, which support the slabs forming the floor or deck.

Each span consists of two reinforced concrete slabs or girders, each slab forming half the width of the floor and having a curb wall to retain the ballast. For trestles of over 5 or 6 spans in length, longitudinal rigidity is obtained by the use of double bents at suitable intervals, consisting of two rows of piles carrying a single cap twice the usual width. In the first of these trestles to be built, a solid pier was used in place of the piles and cap at every sixth bent, but the double bent construction is now considered preferable.

The deck slabs are cast in the railway company's yards, and after seasoning about sixty days are carried to the bridge site and placed in a similar manner to the deck girder slabs described in "track elevation work on the C., B. & Q. R. R." The ballast and track are laid directly on these slabs.

Different proportions of concrete are used for different parts of the trestle. The concrete for the piles is mixed in the proportions of one part cement to three parts fine screened gravel, while for the caps and girder slabs a mixture of 1:4½ with gravel, or 1:2:4 with sand and stone is used.

In constructing these trestles traffic is not interfered with. The floor of the existing timber trestle is partly dismantled and concrete piles are driven to form bents intermediate with the old timber bents. The forms for the caps are then put in place and filled, the concrete being allowed to set about thirty days. Part of the timber trestle is then torn out by a derrick car or wrecking crane and the girder slabs set in place.

Concrete Pier Trestles.—Where longer spans are used and where the trestles cross streams in which floating ice is apt to

occur, thin concrete piers are used in preference to the pile bents. The photograph in Fig. 12 shows a typical structure of this type of 25 foot spans. The piers are carried down to footings on a solid foundation or are supported by wooden or concrete piles.

These trestles are designed and constructed by the Engineering Department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

Overhead Highway Bridges.

Owing to the deteriorating influence of locomotive gases upon the under surface of bridge floors, the construction of overhead highway crossings is one of the greatest problems which railroad engineers are called upon to solve. There are numerous cases where after a few years steel girders and stringers, even when presumably protected by brick arches, have rusted to one-half their original thickness, thus endangering many lives.

Steel girders, when unprotected, have to be painted very frequently, and, as the accumulated rust formed by the locomotive gases has to be removed, this is a much more expensive operation than under ordinary circumstances. To do away with the high maintenance expense and to overcome the effect of the sulphurous fumes from locomotives, old structures are being encased in concrete and new ones are being built either entirely of reinforced concrete or of structural steel encased in concrete. Bridges thus constructed are absolutely unaffected by ordinary rust, rot or fire, and can be designed economically along artistic lines.

First Avenue Viaduct, L. I. R. R.—This viaduct, 788 feet long, carries First Avenue over the tracks of the Long Island Railroad at Bay Ridge, Long Island. It is 68 feet 10 inches wide, and is divided by the main girders into two roadways 23 feet 3 inches wide and two sidewalks 11 feet 2 inches wide.

The main girders, which are supported for about half the viaduct on concrete piers, and the remainder of the distance on steel columns and girders, are riveted steel plate girders encased in concrete to a level a little above the roadway and sidewalk. The photograph in Fig. 13 gives a view of the encased girders from below.

The concrete for the piers was mixed in the proportions of 1 part Atlas Portland Cement to 3 parts sand to 5 parts 1½ inch broken stone, and for the other parts of the structure, in the proportions of 1:2:4 with ¾ inch broken stone.

The floor system consists of 24 inch 80 pound I-cross beams, 11 feet on centers, entirely encased in concrete, carrying a reinforced concrete floor slab. Twisted rods are used as reinforcement.

Before the concrete of the sidewalk slabs had time to set, a granolithic finish 1 inch thick consisting of 1 part cement to 2 parts trap rock screenings was applied and worked until it became an integral part of the concrete and had a dense and smooth surface. The pavement for the roadways consists of a 1-inch binder course with a 2-inch wearing surface of asphalt.

By using hangers suspended from the bottom flanges of the cross beams, the forms for the floor slabs and haunches around the bottom flanges of the steel beams were supported without the use of shoring. The forms for both piers and floors were treated with car journal oil. Immediately after removing the pier forms, which was on an average about 48 hours after filling, the green concrete was floated with water and rubbed by carborundum bricks.

The construction plant consisted of a 5-ton locomotive crane, a ½ cubic yard mixer, two 24-inch gauge cars carrying two ¼ cubic yard buckets and ordinary iron barrows.

The viaduct was designed by the engineering department of the Bay Ridge Improvement Company under the super-

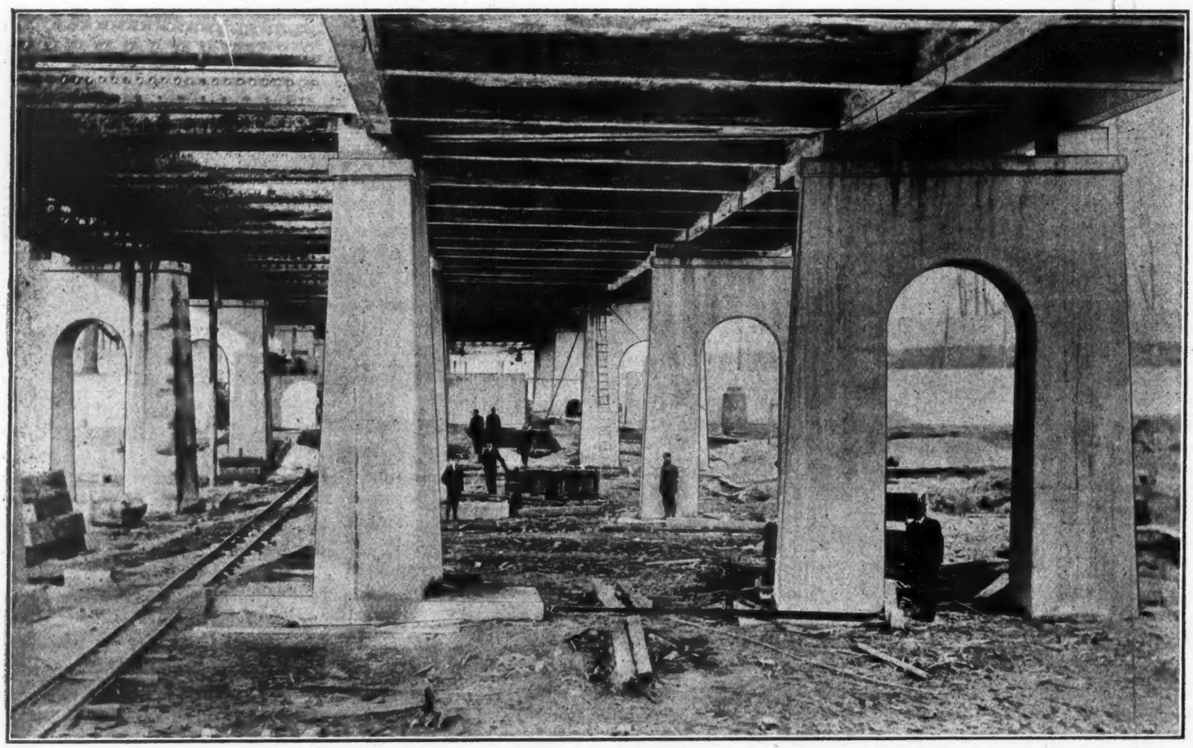


Fig. 13. Steel Girders Encased in Concrete, Long Island R. R.

vision of Mr. L. V. Morris, chief engineer, and the concrete work was done by W. H. Gahagan, contracting engineer, of Brooklyn, N. Y., during the fall of 1908 and the winter and spring of 1909.

Bridge Floors.

Since railroad engineers came to the conclusion a few years ago that the most satisfactory form of bridge floor was a ballasted solid floor, a great many types of wooden and steel floors have been tried. The best of these floors have been very expensive, and while satisfactory for a limited time have proved comparatiely short lived.

A number of railroads throughout the country have designed bridge floors, using reinforced concrete in the form of a slab, that have given absolute satisfaction. The reinforced concrete slab usually rests either directly upon the top flange of the girders when used for a deck bridge, or upon floor beams and girders when used on a through bridge.

A reinforced concrete bridge floor of considerable proportions,—being in reality a railway yard supported on plate girders—which has given marked satisfaction during the period it has been under traffic, is described below.

Reinforced Concrete Bridge Floors, D., L. & W. R. R.—The D., L. & W. R. R. has a mammoth bridge floor, 81 by 349 feet, containing 26,269 square feet of floor space. The concrete is mixed in the proportions of 1 part Portland cement, 2 parts clean sharp sand and 4 parts 1½ inch broken stone. The top layer, which acts as waterproofing, consists of a 1-inch coating of mortar composed of 1 part Portland cement to 2½ parts sand troweled smooth on top. After this layer had thoroughly set the entire surface was given a heavy coat of pure cement grout. The floor slab is designed so that switches and cross overs may be made anywhere.

In the construction of the floor, it was found that the economy involved as to material and labor resulted in a saving of from 30 to 40 per cent from the cost of steel channel floor for the same purpose. A square 10 ft. by 10 ft. contains 3,704 cubic yards of concrete and 718.4 pounds of steel, while a standard channel floor composed of 15-inch channels protected by 4 inches of concrete would contain 1,234 cubic yards of concrete and 2,640 pounds of steel.

This floor was designed by the engineering department of the railroad under the supervision of Mr. Lincoln Bush, chief engineer, and Mr. B| H. Davis, assistant engineer in charge of masonry design.

CHAPTER IV.

Culverts.

Concrete is used to advantage in the construction of all classes of culverts from the small pipe to the large reinforced arch and box types. On account of its greater simplicity and the less expensive abutments required, the reinforced flat top culvert, with abutments of reinforced concrete, is more economical for short spans than the arch type.

As an aid to the design of concrete arch culverts, without reinforcement, a committee of the American Railway Engineering and Maintenance of Way Association submitted to that association in 1908 a composite design embodying a combination of details of construction of plain concrete-arch culverts with the necessary dimensions, selected from the standards of railroads in the United States and Canada, and for this data the reader is referred to Bulletin No. 105 of that society.

Standard 3-Foot Arch Culvert, D., L. & W. R. R.—In the standard 3-ft. semicircular arch of the D., L. & W. R. R., the invert is reinforced with ¾-inch bars, 12 inches on centers transversely, and 2 feet on centers longitudinally, while the arch itself is reinforced in a longitudinal direction with ¾-inch bars, 12 inches on centers. In case rock or shale is found, the invert reinforcement is left out, and the concrete in the invert reduced to a thickness of one foot throughout. In the body of the culvert there are [illegible] cubic yards of 1:2:4 concrete per linear foot.

Indian Creek Culvert, K. C., M. & O. Ry.—Figs 15 and 16 show the Indian Creek culvert before and after filling. As will be seen from the drawings, this is a reinforced box culvert. It is 14 by 15 feet wide and about 250 feet long. An interesting feature in the design of the culvert is the use of reinforced struts spaced 8 feet on centers instead of a solid concrete invert.

In the construction of the culvert, the concrete was mixed in the proportions of 1 part cement to 3 parts Kansas River sand, to 5 parts crushed limestone passing a 2-inch ring and freed from dust by screening. The mixing was done by a No. 1 rotary mixer. The forms were constructed of 1-inch lumber with 2 by 6-inch studs 12 inches on centers. All excavation and pile-driving was performed and the reinforcing bars furnished by the railroad company, who also bore one-half the cost of keeping the foundations dry while the forms were being built and the concrete placed.

The following figures give the unit cost to the contractor and the unit cost to the railroad company, who let the contract on the basis of $9.00 per cubic yard. The costs given covered all labor and materials necessary other than the exceptions mentioned above:

Unit Cost to Contractor.

Cement	$1.37	per cubic yard of concrete
Sand	0.34	" " " " "
Stone	1.10	" " " " "
Labor	2.48	" " " " "
Lumber	0.76	" " " " "
Miscellaneous	0.18	" " " " "
	$6.23	

Unit cost to Railroad.

Excavation, pumping, etc.	$1.84	per cubic yard of concrete
Piles (389) 8,647 linear ft.	2.71	" " " " "
Reinforcing bars, 113,600 lb.	2.56	" " " " "
	$7.11	

Total unit net cost, not including profit ....$13.34 per cubic yard

The culvert was designed by Mr. W. W. Colpitts, assistant chief engineer of the Kansas City, Mexico & Orient Railway, and was built by Mr. L. J. Smith, general contractor, of Kansas City, in the fall of 1905.

Eighteen-Foot Arch Culvert, Bangor & Aroostook R. R.—The photograph in Fig. 17 is of an 18-foot arch culvert on the Bangor & Aroostook R. R., of very simple and at the same time artistic lines. An interesting feature of the design of this culvert is the method employed to protect the soil under the culvert from wash or undertow. This is done by extending the paving, which is of concrete with a minimum thickness of one foot, to the ends of the wing walls, where it makes a vertically downward return to the depth of the bottom of the foundation 5 feet below the bed of the stream or top of paving.

The concrete was mixed in the proportions of one part Atlas Portland Cement to 3 parts sand to 6 parts gravel, and cost, everything included, $6.42½ per cubic yard.

The culvert was designed and constructed by the engineering department of the Bangor & Aroostook Railroad in 1904 under the supervision of Mr. Moses Burpee, chief engineer.

(To be continued.)

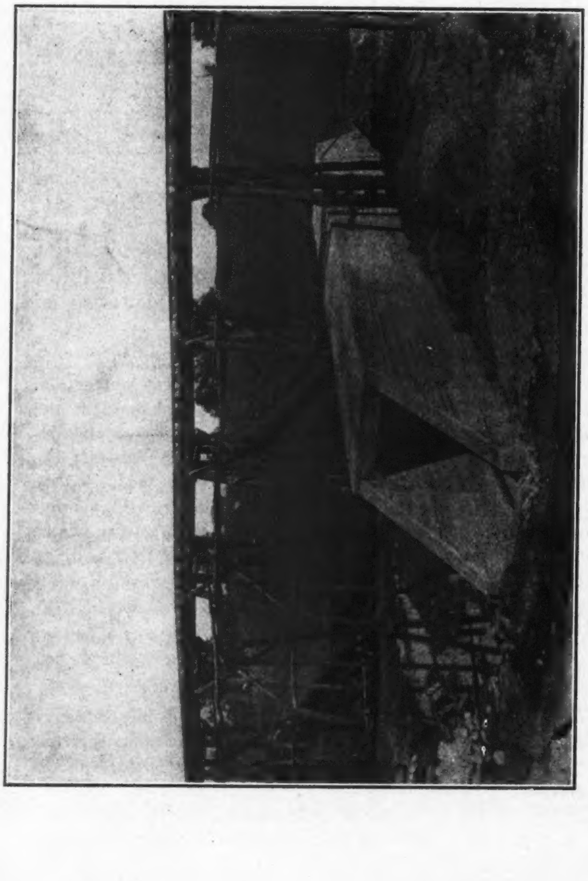


Fig. 14. Concrete Box Culvert, C., B. & Q. R. R.

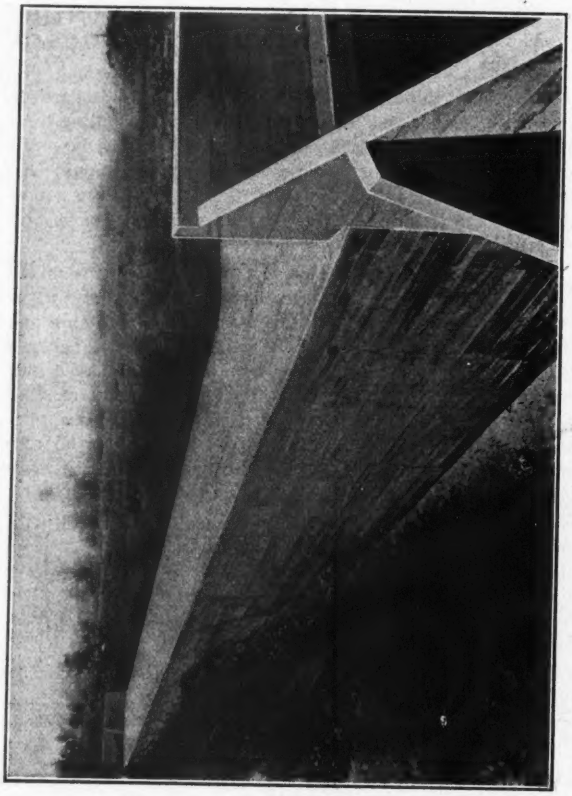


Fig. 15. Indian Creek Culvert Before Filling.

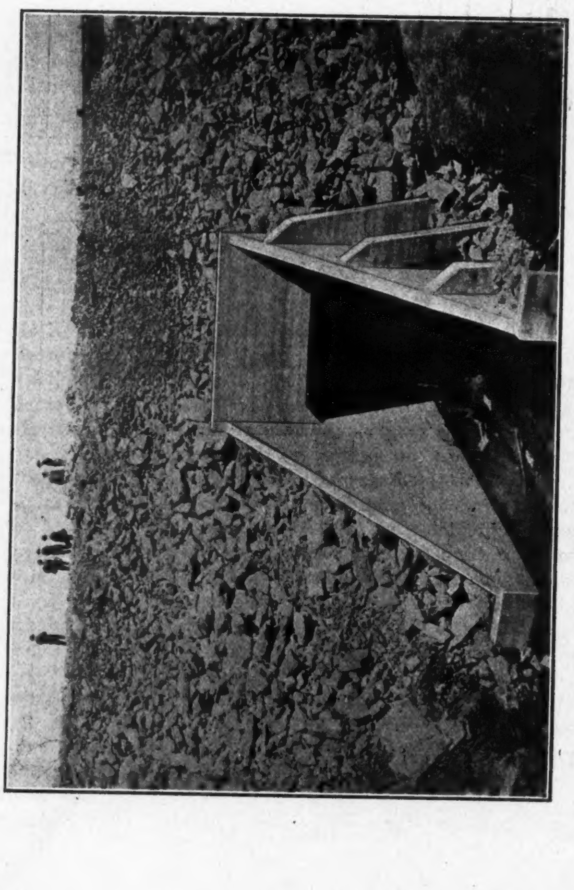


Fig. 16. Indian Creek Culvert After Filling, K. C., M. & O. Ry.

Fig. 17. Eighteen-Foot Culvert, Bangor & Aroostook R. R.

NEW SIGNAL SYSTEM, A. T. & S. F. Ry.

The Santa Fe has in full operation between Kansas City and Holliday a fully equipped modern three-position upper quadrant alternating current block signal system operated from its Argentine power plant, with electric lights for the night signals. These signals will replace the system now in use. The new block signals will have three positions and three signals instead of two, will be lighted with electric lights instead of oil, and will be operated with the alternating current from the power house instead of by individual batteries.

The new signals are being installed under the direction of Edgar Winans, assistant signal engineer of the Santa Fe, who also has charge of the manual block signals on the new double track through to Chicago. The estimated saving in maintenance cost was $60 a month and the time of three out of the four men now used to cover the fourteen miles between here and Holliday. The new system virtually is automatic as to maintenance, working without attention except in case of breaks.

Kansas City Division is protected on the Santa Fe by a primary battery automatic block system east as far as Eaton, twelve miles, and beyond that point and Holliday the manual system is in use.

The Canadian Pacific has given the Illinois Steel Co. an order for 3,000 tons of rails.

The Missouri, Kansas & Texas, it is said, has ordered 20,000 tons of rails.

The Jacksonville Terminal Co., Jacksonville, Fla., has ordered from 800 to 1,000 tons of rails from the Pennsylvania Steel Co.

The Pittsburg Railways Co., Pittsburg, Pa., has ordered 500 tons of standard section rails from the Carnegie Steel Co.

The Great Northern has ordered 436 tons of structural steel to be used in building a machine shop at Hillyard, Mont.

The New Zealand government has placed orders for about 50,000 tons of rails with English mills.

The Haskell & Barker Car Co.'s order of 2,500 tons of structural material is to be used in building a new plant at Michigan City, Ind.

The Great Northern has ordered 30,000 tons of rails from the Illinois Steel Co.

The Texas & Pacific Railroad is reported to be in the market for 16,000 tons of standard section rails.

The Chattanooga & St. Louis has ordered 1,050 tons of rails from the Tennessee Coal, Iron & Railroad Co.

SEVEN YEARS OF PANAMA CANAL WORK.

The seventh year of canal construction by Americans ended on May 4, at which date about 138,000,000 cubic yards of excavation, or more than three-fourths of the entire amount estimated for the completed canal, had been accomplished, leaving only about 44,000,000 cubic yards to be removed. The year was marked by a general advance of the work in amount accomplished, and by a constant decrease in the cost.

A new development of an old factor in the completion of the canal was the increase in the slides in Culebra cut, where the banks have broken in 22 places between Pedro Miguel locks and the Chagres River at Gamboa, a distance of nine miles. An addition of 6,104,000 cubic yards was made to the estimate of the total amount to be excavated, as an allowance for the slides, and the amount in motion, or that has given an indication of probable movement, does not exceed this. This amount may be increased, but this causes no apprehension, as after the locks are completed it will be possible to concentrate dredges for removal of the material that remains and which may slide in, enabling the work to proceed much more expeditiously and much more economically.

Of the total of 44,787,246 cubic yards of excavation remaining, 21,371,975 cubic yards are in Culebra cut. The rate of progress in this section of the work, as compared with other years ending May 1, is shown in the following table:

May 1 to May 1.	Cubic Yds.
1904-1905	648,911
1905-1906	1,250,570
1906-1907	4,861,895
1907-1908	11,285,217
1908-1909	13,955,753
1909-1910	14,886,427
1910-1911	15,925,976
Total	62,814,749
Amount remaining	21,371,975

The placing of concrete in all the locks is 52 per cent completed, 2,153,386 out of a total of 4,284,000 cubic yards having been placed up to May 1, and of this amount 1,694,086 cubic yards were placed in the past year. At Gatun 951,661 cubic yards were placed during the year, and there remain to be placed 783,210 cubic yards before the concrete work is completed. The installing of the lock gates has begun, and the installation of machinery for gate operation and towing of ships, of the emergency dams and operating machines, will be carried on in the upper locks, while concrete laying advances in the lower flights.

A total of 737,425 cubic yards of concrete was placed in the Pacific locks during the year, and there remain to be placed 1,349,576 yards. The locks at Pedro Miguel are nearing completion, and those at Miraflores are fairly begun, and will advance with greater rapidity as soon as the cantilever mixing and handling plant is fully installed.

The estimated dry fill for the toes of Gatun dam is 8,346,778 cubic yards, and there has been placed up to May 1 a total of 7,017,980 yards. It is probable that the amount of material actually dumped in the toes of the dam will greatly exceed the estimated total. The total hydraulic fill is estimated at 11,653,222 cubic yards, and of this amount 7,058,559 cubic yards were in place on May 1. The total estimated fill is 20,000,000 cubic yards, and 70 per cent of this amount was actually in place on May 1.

In the spillway the concrete work is 60 per cent completed, and has reached a stage where it may be continued during the rainy season. There remains to be constructed the concrete dam across the channel, and to be erected thereon the regulating gates.

The relocation of the Panama Railroad above Gatun Lake was completed to such an extent that regular trains may use it between Gatun and Bas Obispo in case high water in the lake region makes the old line between those points impassable. The location on the 95-foot level through Culebra cut was changed to one parallel with the canal, but far enough east of it not to be interfered with by slides.

The breakwater at the Pacific entrance to the canal, extending from Balboa to Naos Island, was advanced to a point 13,000 feet from shore, and now lacks about 4,000 feet of completion. The breakwater at the Atlantic entrance, which will extend from Toro Point about 10,500 feet into Limon Bay, was begun in August, 1910, and on May 1 the fill had been advanced to 4,214 feet from shore.

Plans were approved for terminal docks and basins at both entrances. The basin at the Pacific entrance will be at Balboa, where work has been begun on the first of a series of reinforced concrete docks. The docks at the Atlantic entrance at Cristobal will consist of a series of reinforced con-

crete docks, or slips, reached from shore by a mole which will extend about 3,300 feet into the bay and serve as a breakwater to protect the harbor on the south.

Plans for buoying and lighting the canal and its approaches have been adopted, and the work of clearing the ranges in the lake region has been begun.

The government adopted the policy of fortifying the canal on March 4, 1911, when the bill appropriating $3,000,000 for initial expenditures was approved.

The grand total of canal excavation to May 1 was 137,750,520 cubic yards, leaving to be excavated 44,787,246 cubic yards, or less than one-fourth of the entire amount for the completed canal.

The total for April was 2,691,753 cubic yards, as compared with 2,632,468 cubic yards in April, 1910, and 3,454,649 cubic yards in April, 1909. Of the total, 2,661,088 cubic yards were "work excavation," and 30,665 cubic yards were "plant excavation."

Economics of Tonnage Rating

By J. G. Van Zandt, C. E.

I. Introduction.

There has been considerable discussion regarding tonnage rating in the past and the subject will probably be a live proposition for many years to come. Changes in locomotive and car design, as well as in the method of operation, have made marked changes in the ratings during recent years. Formerly, the question was simply a matter of hauling what cars were ready, and the demands of commerce regulated the load of the locomotive. Growing demands, however, soon approached the limit of the capacity of the engine and it became necessary to designate a definite load as a maximum. The number of cars was used as a basis until it was found that there was so much difference between loaded and empty cars of different kinds, that the number of tons became the basis. It is probably true that both of these items should be considered. Just what the load should be for the mose economical operation is a complex question. The relative economy of running very slow "drag trains" loaded to a maximum, as compared with those of somewhat higher speed has been frequently discussed, and while it often becomes necessary for "time freights" to be operated at a higher speed for commercial reasons, it has been pointed out that, for "tonnage trains," there is a limit of economy in loading a locomotive. The consensus of opinion seems to indicate that from both a mechanical and operating standpoint, the *overloading of a locomotive does not pay.* Not only in the cost of maintenance and repairs to the locomotive, but also in other items, such as fuel consumption per unit ton mile, is there a saving effected by operating freight trains with less than a maximum load. Furthermore, delays due to draw-bar accidents and other lay-overs, which are more likely to occur in drag-train operation, have been expensive indications that overloading is not economical.

The indications from the great mass of data and discussion on this subject of tonnage rating seem to point to one conclusion, viz., that *there is a rating slightly less than the maximum which is the economic load for tonnage trains and which varies with the type of locomotive and the division over which it is operated.*

II. Comparative Cost of Fast and Slow Freight Service.

It has been often demonstrated that the cost per ton-mile for maximum trains and for those not loaded so heavily is nearly the same. Some of these are given below. It has also been observed by investigators in charge of tests that it was "quite possible to get one engine that was large enough to handle a bigger train than was practicable, as a transportation proposition, to move over the road."* It is the purpose of this article to demonstrate that the conclusions of practical experience indicate that there is economy in the long run, taking into account delays and other items usually omitted, in the practice of loading the locomotives somewhat under their maximum capacity. The speed is thus somewhat increased and the length of divisions can therefore be made somewhat longer without exceeding the legal 16-hour trip. "There is a limit to the length (of a division) in that freight trains may not be able to cover it in sufficient time so as not to exhaust the crews."** The trains are also more easily despatched and are not so unwieldly or uncertain at ruling points.

*E. E. R. Tratman—N. Y. Railroad Club, Vol. 12, No. 6.

It was shown by Mr. W. B. Poland, superintendent of the B. & O. Southwestern R. R.,* that after a careful study of the cost of operation on part of that road, "for class 1500 engines, the most economical operation will be attained by trains . . . running 12½ miles per hour and hauling 91 per cent of maximum common rating. For 100 class engines, the greatest economy of operation will be attained by trains . . . running 14½ miles per hour and hauling 97 per cent of maximum common rating." These costs were obtained from records of about 500 trains with actual cost of wages, overtime, helper engine, fuel, repairs, oil, sand, interest on equipment, etc., and include only "those principal items which vary with, or are dependent upon, each trip."

Plate I shows the chart prepared by Mr. Poland in this study of costs and clearly indicates that there was a limit above which it is not economical to load a locomotive and that this limit was from 91 to 97 per cent of the maximum rating, depending upon the type of engine used. The conditions of operation vary widely with the different types of locomotives and the different profiles over which they may be operated, but the same general principle of economy holds true in all cases, viz., *that, if a careful study of each item of operation is made, a scientific rating can be made for each class of locomotive, which will effect the greatest economy.*

The practical question is, then, how can such a study be conducted to produce the most profitable results? A study of this kind resolves itself into two steps, viz.,

(1) Collection of Data.

(2) Co-ordination of Data and Derivation of Conclusions.

(1) Collection of Data.

Much depends upon the methods used in taking records of freight train operation, and probably some of the differences which have appeared in the conclusions of those who have investigated these matters are due to this fact. Many have sought for the desired information by the systematic method of using special test-trains with dynamometer cars and other special equipment. Others have used the somewhat less expensive method of making a careful study of the records of operation of trains in service. Both of these methods have their advantages and disadvantages. There are many advantages in the more complete and scientific method of test train records with special equipment. The special characteristics of the profile and locomotive in question can be determined with fewer tests and with more certainty, when other items which "service tests" might include are excluded. There is also an accumulation of data in the test train method, which, once obtained, can be used for many other problems in operation. In making special

*Bulletin No. 56, American Ry. M. M. Assn.
**Henderson—Cost of Locomotive Operation, p. 160.

test-train records, however, conditions are not the same as in regular service. Locomotives are generally in better condition and handled more carefully and test-trains are generally abnormally uniform in character. While for scientific reasons all these conditions are desirable if the "maximum rating" is desired, it is probable that the results can not be considered as of quite the practical value that the same would be had the locomotives been taken directly in service with regular trains, and a general average secured from a large number of tests. It is probable, going to the other extreme, that the method of simply taking the records of time, fuel, etc. from the regular records as turned in, is not as satisfactory a foundation for a study of the economics of tonnage rating as might be desired because of the many practical difficulties encountered in securing the accurate data unaffected by the personal equation of the men engaged in the work. It is necessary to take a large number of service tests in order that the average values shall be indicative of the desired results. Even a large number may not be satisfactory if the method of taking the data is inaccurate. The actual fuel used on the trip, for example, may be very different from that indicated by the records, as the amount in the tender before and after the run may not be mentioned. The actual running time from which the average speed is desired, may also include certain stops or delays and hence seriously alter the record. It appears, therefore, that it is best to combine the two methods by taking a few road tests with a dynamometer car, and also by making a complete study of carefully collected service data. The function of the road tests would be to determine the train resistance over the division and the maximum tractive force of the locomotive and also such other data as to fuel, etc., which might be desired. The function of the study of service data would be to determine what reasonable "service ratio" should be applied to regular runs to effect the most economic operation.

(2) Co-ordination of Data and Derivation of Conclusions.

It has often happened that after a large quantity of valuable data has been collected, much of the value has been lost because of inaccurate co-ordination and compilation. Apparently worthless data may often become of much value when properly co-ordinated with the conditions under which they were taken. It is not the purpose of this article to discuss statistical methods, although there is a great need of better methods on the part of engineers interested in locomotive operation, but it is evident to those familiar with the facts that the study of the correlation of factors which vary dependently is not merely a plotting of points and then drawing a line of averages among them for a result. There are numerous definite statistical rules which not only require the exclusion of certain extreme values involving extraneous influences, but also include the recognition of the separate factors of the variation, and which in other ways contribute to the accuracy of the result. It may be said, however, that the "probable error of the mean" or the accuracy of the average value depends largely on the number of variates taken, and the care in compilation and co-ordination. Graphic methods are always desirable to check computations, but the "weight" or influence of values is not easily ascertained without proper mathematical consideration.

Mr. G. R. Henderson in "Locomotive Operation" points out that the fuel consumption is greatly influenced by the speed element. In an illustration he has shown that "the coal per ton mile will be greater by about 50 per cent for a 3,500 ton (freight train) than for one of 2,500 tons." There are, of course, other fixed charges which remain, in total, about the same for both trains and thus favor the large tonnage—but there are many other items often omitted such as increased repairs, delays, longer sidetracks and overtime, which, with this large item of fuel economy, overbalance the wages of crews—which does not always remain constant—and other "fixed charges" which favor maximum trains. Henderson shows that the total cost is higher at both extremely low and high speeds and shows a minimum between, which varies with the engine used and division over which it operates. In one illustration it is shown that the same minimum of $0.90 per 1,000 ton-miles may be obtained with a tonnage of from 900 to 1,200 tons. This is not taking into account the cost of delays and other items mentioned in this article which it is found place heavier costs on the higher tonnages and therefore favor the more reasonable loads. It appears necessary, therefore, that a special study be made of the locomotive division in question in order to decide what is the "economic tonnage rating." It is obvious that, as Henderson has said, "In order to make a careful study of any special case, diagrams should be made to suit the particular engine and conditions involved." There may be undulating profile conditions under which without even taking delays into account, the cost may be less for lighter trains. This was found true in a series of tests made recently by the author for establishing a fast freight tonnage rating. The following is an outline of the steps taken in the investigation:

(1) Actual road tests on the division.

(2) Accumulation of theoretical data and checking same by actual tests.

(3) Determination of the relation between coal and water consumption and speed.

(4) Determination of the relation between tonnage and speed.

(5) Determination of the cost of operation at various speeds.

Locomotive tests are not always representative of actual conditions and have been generally run on engines just out of the shops, with a special test-train and schedule. The results so obtained do not indicate service conditions, so, in this investigation, tests were made on service trains which were representative of actual service conditions.

The amount of coal used per 1,000 ton-miles and the pounds of water evaporated per pound of coal agreed closely with the results obtained in tests made by Mr. Garstang on the Cleveland, Cincinnati, Chicago & St. Louis Railway, and published in the proceedings of the Western Railway Club, 1901.

The relation between the coal consumed in the firebox and the speed of the train was determined in the following manner:

(1) An investigation into the waste of steam on account of radiation, safety valve, etc.

(2) A determination of the volume of steam required for operation under ordinary conditions, based upon indicator card tests.

(3) A computation of the quantity of coal necessary to produce the volume of steam required at various speeds.

It is evident that this determination gives a theoretical coal consumption based upon indicator card tests. Checks with the actual road tests and averages of coal consumed (from the reports of the chief engineer) show that it is not far from that found in actual practice. Indicator test cards were also available from the reports of the chief engineer, by the use of which the volume of steam required at different speeds could be determined. For amount of coal required to evaporate the water used, the work of Professor Goss and Mr. Garstang at Purdue University was taken as a basis of comparison, the average being about 6 lbs. of water per pound of coal. Results were plotted (Plate II) and show clearly how coal consumption varies with the speed, the greatest economy being attained at the speed of about 33 miles per hour. A point of special interest in this

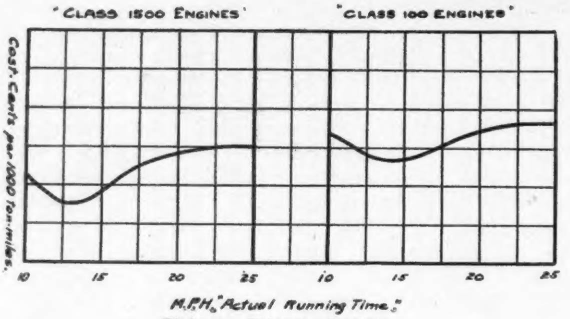


Plate I.—Poland's Results.

curve is that it shows the consumption of coal of the different classes of locomotives to vary in the same way, the points being intermingled along the same curve; which was checked by road tests. The first check was made by selecting those parts of the speed records in which tonnages were somewhat uniform for all the tests, and plotting below them the curve of actual coal consumption per mile. This gives a good check and shows that theoretical deductions based on the indicator cards taken were not far from the actual conditions. In order that a fair comparison could be made of the costs of operation at various speeds, the cost was considered on the "ton-mile" basis. To do this the necessary relation was determined between the tons hauled and the average speed by plotting a curve of arbitrary stops from the dispatcher's records. It was simply necessary to add the stopping time at a given tonnage, to the running time previously found for the same tonnage. This sum divided into the total miles gave the average speed.

The costs on the test being described were figured on a unit of 1,000 ton-miles, only those items being considered which would be likely to vary with tons hauled and the speed, a summary of the results being given in Table I.

Table I.—Summary—Table of Costs.

1. Average speed between terminals	10	15	20	25
2. Weight of train, back of tender	1,620	1,550	1,070	700
3. Actual time, hours between terminals	14.47	9.65	7.25	5.80
4. Coal burned, lbs. per mile	375	238	168	125
5. Coal burned, lbs. per 1,000 ton-miles	231	153.5	157	179
6. Water used, gallons per mile	215.5	154	104	85
7. Water used, gals. per 1,000 ton-miles	133	99.5	97	121
Cost per 1,000 Ton-Miles.				
8. Cost of coal burned	.243	.161	.165	.188
9. Cost of water used	.0133	.0099	.0097	.0121
10. Cost of repairs	.145	.159	.168	.196
11. Pay of enginemen	.047	.050	.072	.111
12. Interest allowance	.0107	.0103	.0117	.0145
13. Cost of car repairs	.150	.150	.150	.150
14. Pay of trainmen	.0567	.0593	.0860	.1310
15. Total cost	.6657	.5995	.6624	.8026

The cost of coal on this division was $2.10 per ton (average) and the cost of water was assumed at 10 cents per 1,000 gallons, as given by Henderson, although it was perhaps high for this road, on which, however no actual data was obtainable. The costs of locomotive and car repairs were taken from Henderson's determinations as being 15 cents per 1,000 ton-miles. The pay of engineers and firemen is based on a schedule of 100 miles or less, or 10 hours or less per day. The interest allowance was also assumed as figured by Henderson and amounted to $2.50 per day, or practically 10 cents per hour. In line 15 the sum of the different columns is shown and represents the comparative costs of operating, per 1,000 ton-miles. Plate III shows the economical speed for freight trains on this division is somewhere near 15 miles per hour. The curve also shows clearly how the cost increases both at the slower and at the faster speeds.

The results in this table do not, it must be remembered, represent the total operating charge per 1,000 ton miles, which would probably be a great deal more. The results are of interest in view of the fact that at the time most of the trains were made up on this division on the basis of 10 miles per hour, whereas it appears from these computations that an average speed of 15 miles per hour would result in a decided saving.

III. Train Resistance.

Perhaps there is no item which is more vitally connected with the economics of tonnage rating than train resistance. Unfortunately the results of the many investigations of this important factor appear to differ so widely that there is much difference of opinion in regard to the matter. In general it may be said that these differences can usually be assigned to the unlike conditions under which the tests were made and to the inadequate co-ordination of all the factors involved. It would be perfectly evident that a locomotive hauling passenger cars on a perfectly maintained track would have a different resistance to overcome per ton of train than one hauling old freight cars over a rough track. Yet many of the "train resistance formulas" have been fabricated under even more widely divergent circumstances than these, with the inevitable result that the conclusions do not agree. It is probable, however, that with due regard for all these factors it can be shown that there is comparatively little difference between the actual results of these tests which have been made. When the values obtained from tests actually cover a diagram, it is evident that there must be other items influencing the variation than the speed, and in order to determine what these items are, and how much they influence the values, a careful analysis must be made. The factors which go to make up the resistance of cars in a moving train are many and difficult of determination. In general they may be classified as follows:

1. Acceleration.
2. Grade.
3. Friction; divided as follows:
   - (a) Journal friction.
   - (b) Rolling friction.
   - (c) Flange friction.
   - (d) Air friction.

There is such an accumulation of data upon each of the several items above mentioned and careful investigations differ so widely in their conclusions, it is evident that one would not be justified in making extended investigations for minute discriminations. Each factor was therefore investigated, in the case used as an example, in so far as that investigation promised to be fruitful of information of value.

(1) Acceleration.—The figures given by Wellington were adopted in the computations as an average representing a fairly well selected value for ordinary conditions.

(2) Grade.—Grade resistance in pounds per ton is equal to 20 times the rate of grade in percent, this being an accepted rule credited to Wellington.

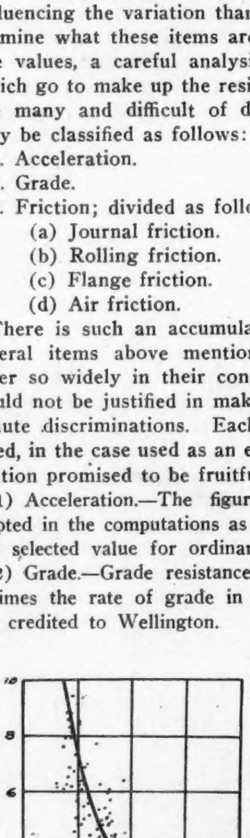


Plate II.—Coal Consumption.

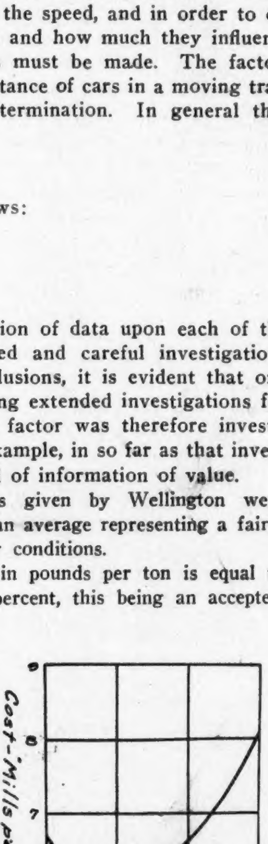


Plate III.—Variation of Costs.

(3) Friction.—(a) Journal friction depends upon the design of the journals and lubrication, and varies with the number of journals and the pressure upon them. *Speed does not materially affect this factor AFTER it reaches that value at which a continuous film of oil is kept running between the surfaces in contact.*

(b) Rolling friction is the friction caused by the wheels in contact with the rails as if there were no flanges. It is generally conceded to be due to a peculiar wave in the rail just in front of the wheel as it depresses the track with its weight; this friction therefore would vary as the weight upon the wheels and the conditions of the roadbed. The size and shape of the rail and the size of the wheel would also affect this factor, together with other minor influences, such as line, surface, snow and dirt.

(c) The term "flange friction" denotes all other resistances between the wheel and the rail not included in rolling resistances. On level tangent this factor is largely dependent on design of the rail and flanges.

(d) Air friction. Besides increasing the flange resistance (as when a wind is blowing against the side of a train) the friction of the air against the sides and the suction at the back of the cars would increase the total resistance somewhat.

For miscellaneous factors seemingly impossible of determination the term "oscillation and concussion" is used. The hundred or more train resistance formulas may be arranged into four general forms, all of which deal only with frictional resistances, constants being used for journal friction and for the remaining resistance; sometimes exclusive of wind friction which is given as a separate factor varying as the square of the speed. A very few formulas take into consideration the size of the train, but even these do not mention the size of the car bodies or wheels, or the number of wheels to the car.

That these items might reasonably be expected to influence the resistance is evident. Rolling stock has been constantly changing in weight and other dimensions, during the years producing train resistance formulas. The practice of simply plotting the train resistance values against the speed, as if

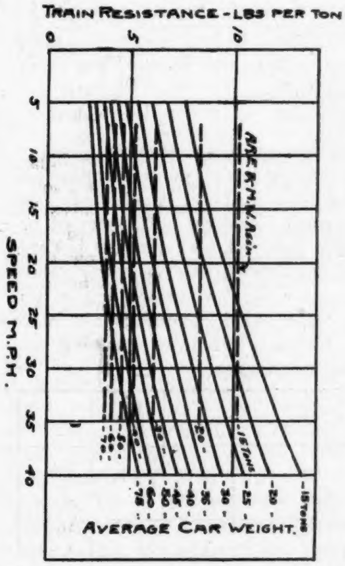


Plate IV.—Train Resistance.

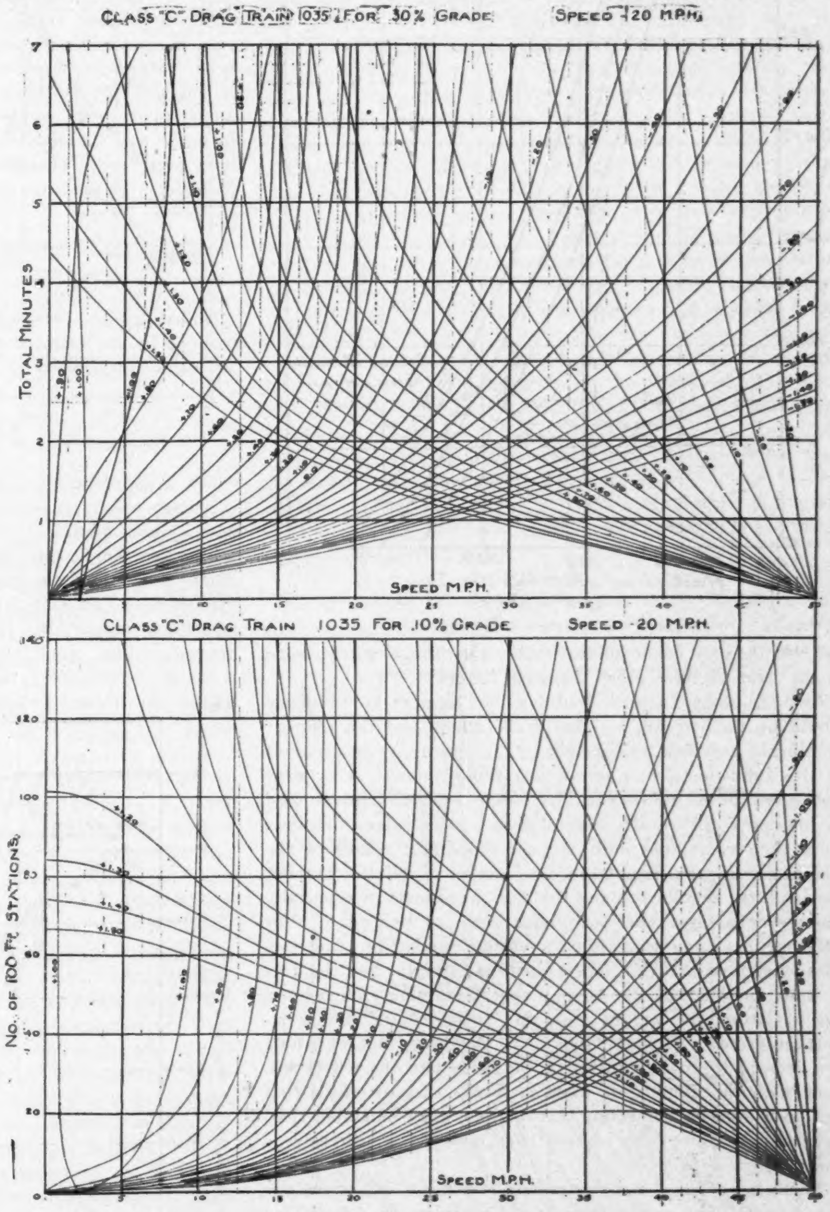


Plate IX.—Operation Chart.

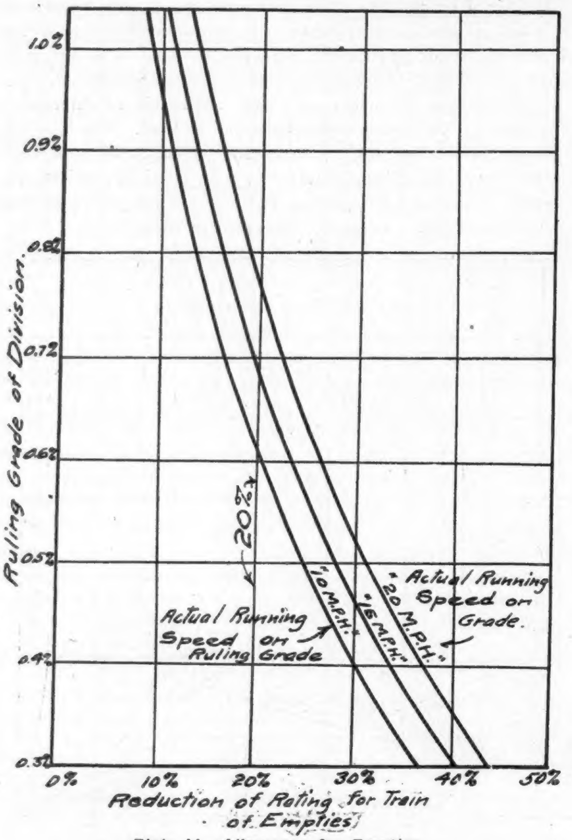


Plate V.—Allowance for Empties.

that was the only factor influencing the variation, is unreasonable in the light of these other changing factors.

Among other factors doubtless an important influence would be the varying weight of the trains and the number of wheels carrying the weight. To determine the amount of this influence a number of test records made at or near the speed of 10 miles per hour were selected and studied in obtaining the results herein given. The values obtained were then correlated with the corresponding values of the weight of the train divided by the number of wheels carrying the load, the results proving that for these tests of especially uniform character the correlation was 45 per cent. For heterogeneous conditions the increasing number of other factors would reduce this figure correspondingly, but the fact is apparent that of the 55 per cent remaining influence in the variation, the weight upon the "wheel units" is an important factor. It is obvious that all those factors which are derived from the contact of the rails with the wheel will vary with the number of wheels. From a study of all that has been done to determine this factor it may be stated that, generally speaking, the journal friction will vary directly as the number of wheels.

There is evidence that the rolling resistance in pounds per ton is not increased when a truck contains six wheels instead of four. The rolling resistance caused by the elastic wave in front of the wheels is materially less for two trucks of six than for three trucks of four wheels each, since the wave made by the first wheel affects the second only slightly, and hence two instead of three waves will be made. The rolling resistance would reasonably vary inversely as the number of wheels in the truck.

Under normal conditions on a straight level track flange friction is, no doubt, much less in two six-wheel trucks, since the alignment and rigidity favor reduced friction. The same might be said of oscillation, concussion and other miscellaneous friction factors. On curves the resistance will also be much less, for the number of flanges cutting the rail will be less. Taking a general view of the matter it may be stated that rail resistance varies in pounds per ton inversely as the number of wheels carrying the load.

Applying these two principles in a preliminary way to two of the most famous and well established formulas for train resistance, a reconciliation is found that shows that both may be right. They were both derived from experiments made on a good track, under practically the same circumstances, and while ranges of speed were not wide, they have been extended experimentally and substantially checked throughout. It has been stated that there were 5,000 experiments made from which the present "Baldwin Locomotive" formula was derived, the records unfortunately not having been preserved. These experiments, however, were made on 12-wheel high-speed passenger cars. The formula is usually written as follows:

$$R = 3 + \frac{V}{6}$$

Adjusting this for 8-wheel freight cars, the first factor is reduced by the ratio of 12 to 8 and the second increased by the same ratio, hence it becomes,

$$R = 2 + \frac{V}{4}$$

which is the celebrated "Engineering News" formula.

Numerous charges have been made that these formulas are based upon figures derived from tests on track, "some of which are the best in the world," and do not represent ordinary practice; these charges have not been justified by later experiments. In fact, later formulas give even lower values and the evidence that these are too low grows less as improved rolling stock and better road conditions are more common. The older the formula, generally speaking, the higher the values obtained by its use.

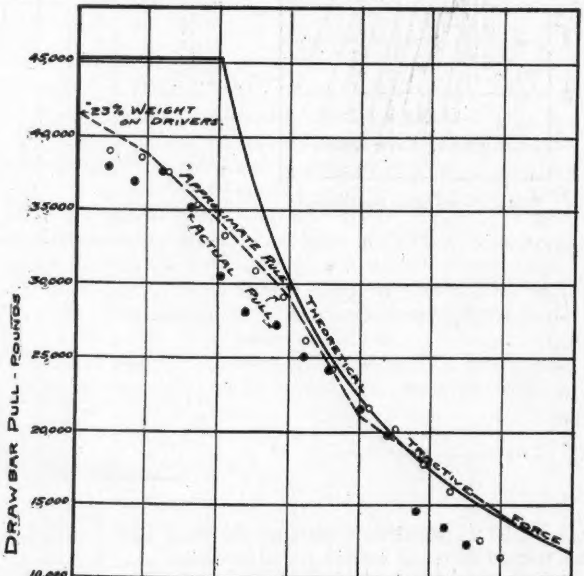


Plate VI.—Tractive Force.

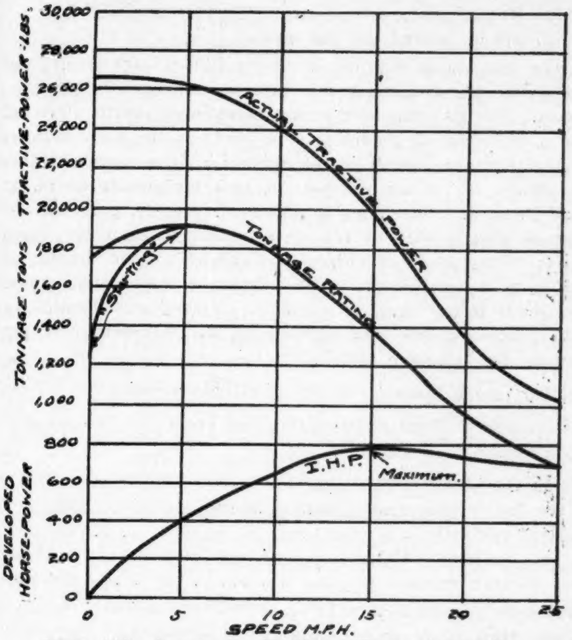


Plate VII.—Curves for 800-Horse Power Locomotive.

Considering this practical reconciliation the "wheel unit" of the type of freight car in use would present a practical basis. A number of references have been made to the importance of this wheel unit, Mr. Delano stating that, "the number of wheels and the length of the train are important factors," in train resistance. It might be possible to reduce all present formulas, as in the above case, to the freight car unit, or even to the basis of the number of wheels and the weight on them.

A most valuable contribution to this subject has recently been made by Prof. E. C. Schmidt, in Bulletin No. 43 of the Illinois University Engineering Experiment Station. The relation of "average car weight" to train resistance is very clearly indicated by the tests. Plate IV is a diagram showing these relations and indicates that as the weight increases not only does the resistance in pounds per ton decrease, but the effect of the speed is very much less. The careful methods employed in the development of these curves should commend them to a wide acceptance. One thing is certain, and that is that there is a general inclination of the curves giving an increased value for higher speeds. The results of Mr. A. C. Dennis and the conclusions of the American Railway Engineering and Maintenance of Way Association (Bulletin No. 120) which were influnced by his conclusions, are also indicated on Plate II in broken lines showing no change "between 7 and 35 miles per hour". There are so many factors in train resistance which individually do increase with the speed, it appears logical that the sum total would be influenced to do likewise. One reason why many experiments with test cars have not evidenced this fact is that most of the records for low speeds were taken at or near the start of the tests when conditions were not normal. It is a known fact that it takes some time for the bearings to get "warmed up" and well lubricated, and that records taken before these conditions have been attained will invariably give higher values at lower speeds—which would in time make the curves appear more nearly level. It may be pertinent to suggest that this peculiar characteristic of train resistance makes it especially desirable that freight trains should be kept in motion in order to effect economy of operation, and not stopped frequently as is the common practice. Of course, this is a matter of operation which cannot be easily solved, but it appears that since the actual number of foot-pounds of energy necessary to move a train can be reduced so considerably by the simple process of avoiding long delays which permit the train to become "froze", that it should receive more careful attention. Possibly this may be one of the principal reasons why the faster freight trains can be run more economically than those of maximum tonnage. As an example, suppose it requires twice as much power to pull a freight train over the first mile (since the tests indicate that it may) on account of being delayed long enough to become "froze". Then the extra cost of hauling that train that one mile would be correspondingly greater because of the increased demand upon the locomotive, which means increased fuel consumption and possibly stalling, with resultant delays, overtime, and repairs. It is evident that there is a saving of considerable amount if after the train is once in motion it may not be required to stop long enough at any point to increase the resistance materially. It was found by the examination of a series of service records on fast and slow freights, that the delays, including regular stops for coal and water, passing other trains and drawbar pullouts, breakdowns, etc., for "tonnage trains" increased the time from 3 hrs. to 7 hrs. on each run, with an average of nearly 5 hours, whereas for the faster trains the "total delays" ranged from 1¼ hrs. to 2½ hrs., with an average of only 2 hours and 20 minutes.

It appears from all the present data on the subject that the results of the long series of careful tests made by the test car of the University of Illinois Engineering Experiment Station are the most reliable, and these have therefore been adopted in this study.

Empties.

An allowance for empties must be made for it is well known that "empties pull harder than loads"—a practical acknowledgment in the extreme cases that train resistance

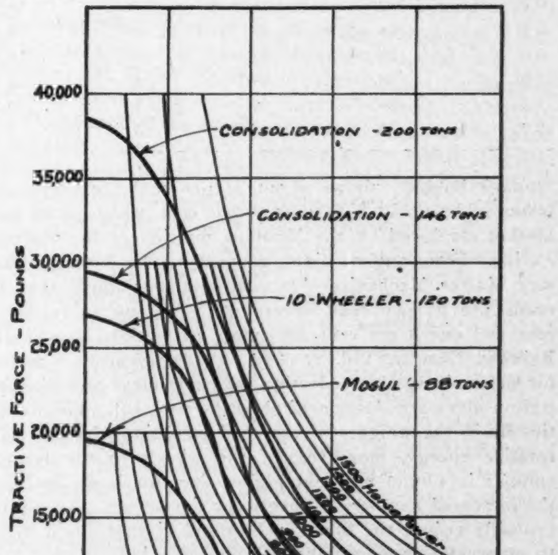


Plate VIII.—Standard Horse Power Curve.

is affected by the average weight of the cars. The term "empty" is only comparatively indicative of the weight of a car. Development in car building has been so rapid in recent years that many of our modern "empties" weigh as much as the full "loads" of former years. Referring to the chart of Plate IV assuming 16 tons for empties and 50 tons for loads, the resistance on level track at 10 miles per hour would appear to be about 8 lbs. per ton for empties and 4 lbs. per ton for loads, a difference of 50 per cent. Of course, the effect is not so great on grades since this difference is a smaller per cent of the total resistance. Assuming 20 lbs. per ton per 1 per cent of grade the total effect upon an empty on a 1 per cent grade is 20+8 or 28 lbs. per ton, and for a load on a 1 per cent grade is 20+4 or 24 lbs. per ton, or a difference of 14.3 per cent instead of 50 per cent. Table II shows the effect for other grades and the allowance may be made by reducing the regular rating the per cent given for the ruling grade of the division to allow for increased resistance of empty cars. The Santa Fe, as shown in its

TABLE II.
Allowance for Empties on Grades.
Ave. empty = 16 tons, Ave. load = 50 tons at 10 M. P. H.

Grade.	Lbs. per ton R. of Empties.	Lbs. per ton R. of Load	Diff.	Diff. in per cent of Load.
0.0	8	4	4	50 %
0.1	10	6	4	40
0.2	12	8	4	33.3
0.3	14	10	4	28.6
0.4	16	12	4	25
0.5	18	14	4	22.1
0.6	20	16	4	20
0.7	22	18	4	18.2
0.8	24	20	4	16.6
0.9	26	22	4	15.4
1.0	28	24	4	14.3
1.5	38	34	4	10.5
2.0	48	44	4	8.3

tonnage booklet, allows about 14 per cent for very heavy trains. The C., B. & Q. uses 23 per cent, which is the same as that employed on the Montana division of the Northern Pacific. From an investigation made by the American Railway Master Mechanics' Association it was found that two roads use 25 per cent, several 20 per cent, three 10 per cent and one 8 per cent for empty cars. Mr. Haas, in the Railroad Gazette, Vol. 27, 1895, p. 129, presents a method for determining this reduction by experiment and his illustration gives a deduction of about 24 per cent. The difficulties lie in the weights of cars and condition of track. The rotative energy, moreover, of the wheels in the train of empties is 4 or 5 per cent higher than for loads, owing to the increased number of wheels per ton weight. This would probably reduce the higher values and gives a slight benefit to empty trains in making a "run for a hill" in that there is more momentum per ton of train due to the larger per cent of wheels per ton containing rotative energy. Without having the data regarding the grades or speeds used in the above cases it is not possible to ascertain their bearing as a check on these computations. They do indicate a tendency to make allowance of about 20 per cent, which is the value here found for a 0.6 per cent grade and a speed of 10 m. p. h., with average weights of empties at 16 tons and loads at 50 tons. It is probable that the following items should always be considered in making allowance for empties:

(1) Average weight of cars.

(2) Ruling grade of division or "virtual grade."

(3) Speed desired on that grade.

For fast trains this allowance for lighter cars should not be quite the same since the ratio of resistance is not constant. The allowance for trains maintaining speeds above 10 m. p. h. on ruling grades may be found in the same manner using the values for train resistance for those speeds. Plate V shows the values of these factors for speeds of 10, 15 and 20 m. p. h. on ruling grades from .3 to 1.0 per cent. It can be clearly seen by reference to this diagram that for a given ruling grade of 0.6 per cent and for a train running at 10 m. p. h. on this grade the allowance for empties would be about 20 per cent, or one-fifth. A simple application of this conclusion has been effected by the following note put below the "tonnage table":

"For empties deduct one-fifth of the above rating."

Example: What is the rating for Train No. 28 with Engine No. 248, all empties?

From the above table, rating for loads is found in the last column, next to bottom line to be	1,345
Deduct one-fifth	269
Balance empties	1,076 tons

Again: Train No. 22, Engine No. 172 has 915 tons of load. How many tons of empties will fill out the rating?

		Tons
From the table the rating for loads is	1,865	
Load on	915	915
Balance	950	
Deduct one-fifth	190	
Balance empties	760	760
Total tonnage is		1,675

This method has been found to be satisfactory and has the advantage over "distribution tables" that it is more exact and more easily used. Any trainman can understand its workings and it is so simple that after it has been used a few times the adjustment for empties can be made mentally.

A Method of Adjusting Tonnage Rating for Partially Loaded Cars.

Derivation of formulas—

Let A = Tons on train.
B = Number of cars on train.
C = Rating to be filled out in train.
X = Equivalent number of loads, at 45 tons average.
Y = Equivalent number of empties at 15 tons average.

$$45X + 15Y = A$$

$$X + Y = B$$

Combining, $X = \dfrac{A - 15B}{30}$ = Number of loads on train.

$Y = B - X$ = Number equivalent empties on train.

Deduction (assuming 20 per cent for empties):

(1) $\dfrac{(C - 45X)\ .80}{15}$ = Number of empties to fill out rating.

(2) $\dfrac{C - 45X}{45}$ = Number of loads to fill out rating.

Now, if partially loaded cars are to be added, the per cent of "equivalent empties" $= 45 - \dfrac{\text{(Average weight of all cars)}}{30}$

Average weight of cars in train or to be put in train is a measure of the per cent of equivalent empties, in a corresponding train of loads or empties only.

Table III.

Average weight	—Per cent— "Equiv. empties"	Rating is reduced	Average weight	—Per cent— "Equiv. empties"	Rating is reduced
45 tons	....	....	29 tons	53.3	10.7
44 "	3.3	0.7	28 "	56.4	11.3
43 "	6.7	1.3	27 "	60.0	12.0
42 "	10.0	2.0	26 "	63.0	12.7
41 "	13.3	2.7	25 "	66.7	13.3
40 "	16.7	3.3	24 "	70.0	14.0
39 "	20.0	4.0	23 "	73.3	14.7
38 "	23.3	4.7	22 "	76.7	15.3
37 "	26.7	5.3	21 "	80.0	16.0
36 "	30.0	6.0	20 "	83.3	16.7
35 "	33.3	6.7	19 "	86.7	17.3
34 "	36.7	7.3	18 "	90.0	18.0
33 "	40.0	8.0	17 "	93.3	18.7
32 "	43.3	8.7	16 "	96.7	19.3
31 "	46.7	9.3	15 "	100.0	20.0
30 "	50.0	10.0			

Rule:

(1) Divide tonnage on train by number of cars.

(2) Increase tonnage on train by per cent in column 3, Table III [that is, multiply tonnage (on train) by that per cent and add result to tonnage on train].

(3) Subtract result thus obtained from tonnage rating and reduce that by same per cent if cars to be added have same average weight, or, if not, by the correct per cent for them.

(4) This result is tonnage to be added.

Example:

Given:

A = 1,000 tons, B = 25 cars; now on train.

C = 1,540 rating for division.

Required: How many cars at average weight, 37 tons, can be taken.

(1) $\frac{1{,}000}{25}$ = 40 tons average in train, or 16.7 per cent equivalent empties (Column 2, Table III).

(2) 1,000 + (3.3 per cent 1,000) = 1,000 + 33 = 1,033 tons.

(Column 3, Table III.)

(3) 1,540 − 1,033 = 507 tons balance, to be reduced 5.3 per cent. (Column 3, at 37 tons average weight.)

$.947 \times 507 = 480.$

(4) 480 tons or $\frac{480}{37}$ = 13 more cars.—Answer.

IV. Tractive Force.

The conclusions of the Committee on Economics of Railway Location of the American Railway Engineering and Maintenance of Way Association, given in Bulletin No. 120 on tractive force, have received unanimous approval in the recommendation that the "actual drawbar pull" as determined by test car records should be used. The methods suggested for calculating the tractive power, in case it is not known by actual test, have not met with as hearty approval largely because of the wide differences of opinion as to the constants and friction factors employed, together with the omission of some factors which it has appeared should be considered. It is probable that no formula or simple computation method can be made to meet all the variable quantities involved. It is known, for example, that differences in kind of fuel, water, and lubrication, also in the setting of valves and adjustment of draft in front-end, not to mention efficient firing and operation or general condition of repair, have marked influence upon the tractive power of the locomotive. It seems desirable, however, that some approximate method be available for rough computations and probably that proposed is as good as any. However, the labor involved in the use of the method does not appear justified in the approximate results obtained. A report of the Association of Transportation and Car Accounting officers (Circular No. 83) uses the tractive power as constant for all speeds from zero to twenty miles per hour! The result, of course, shows a "possible gross tonnage" for trains making an average speed of 20 miles per hour much greater than for the lower speeds. For approximate computations of this nature *where the actual tractive power is unknown* the following simple method is suggested:

Speed Miles per Hour	Tractive power in per cent of weight on drivers. (Simple freight locomotive designed for low speed.)
0	23% (30% for starting with sand)
5	21
10	19
15	15½
20	12
25	10
30	8
35	7½
40	7
45	6½
50	6

The speed, however, should best be put in terms of "revolutions per minute" or "piston feet." Probably many of the extreme values suggested have been due to unreasonable coordination of this data.

Most computations of tractive power are based on the fundamental formula of "work done" or

$$\text{T. F.} \times \text{D} = 4 \text{ M. E. P.} \frac{d^2s}{4}$$

from which $\text{T. F.} = \frac{\text{M. E. P. } d^2s}{\text{D}}$

The voluminous tables of the American Locomotive Company are based on this formula, using 85 per cent of boiler pressure as "M. E. P." It appears from numerous tests that at starting about 90 per cent B. P. may be used. If this exceeds 23 per cent of the weight on drivers, sand may be used, but 30 per cent adhesion is the maximum which may be expected even with sand. In order to discover the point at which speed becomes the controlling factor the evaporating power of the boiler must be computed and equated to the speed requiring an equal volume (corrected for pressure) in the cylinders. This speed usually falls at about 10 M. P. H., depending upon the design of locomotive. For speeds above this point the larger cut-off must be employed, and the tractive-force reduced accordingly. Many theoretical curves have been devised for this, but it appears that if the test car results are not obtainable the computations should be based upon indicator card tests. The "M. E. P." thus found may be considered as acting directly upon the drivers, though the friction of the locomotive must be subtracted. It is also evident that the tangential tractive force is reduced because of the mechanical construction of the leverage.

Taking the work done again, for both sides per revolution, we have:

$$2 \times 4 \text{ M. E. P.} \times \text{stroke} = 2 \times 2\pi \times \text{stroke} \times \text{F or}$$
$$\text{F} = .6366 \text{ M. E. P.}$$

where "F" is the tangential force on crank pins. But the tractive force "T. F." at the rim of the drivers is proportionately reduced thus:

$$\text{T. F.} \times \tfrac{1}{2}\text{D} = \text{F} \times \text{stroke or T. F.} = \frac{.6366 \text{ M. E. P.} \times \text{stroke}}{\tfrac{1}{2} \text{ diameter of drivers}}$$

Of course the force in the piston is not a constant "M. E. P.," nor is the connecting rod in a position to give maximum thrust when the pressure is highest. Henderson gives an

analysis of the action showing a wave-like action with some decided points of maximum ability. The length of connecting rod and proportion to stroke influence this action considerably. When this ratio is one to five the action in the forward half has 58 per cent of the total thrust of one-half revolution. The resistance of the locomotive and tender as well as their momentum should not be forgotten in considering tractice force by computation methods.

Five values for the tractive power of the locomotives selected have been worked out in parallel for comparison, the method employed being as follows:

(1) $T.F. = P_1 C_1 - R_1$

$P_1 =$ M. E. P. from tests above made and described.

$C_1 = \frac{d^2 s}{D}$ a constant for each locomotive. $R_1 =$ the internal resistance from Prof. Goss' formula: $R_1 = 3.8\ C_1$.

(2) $T.F. = P_2 C_1 - R_2$.

$P_2 =$ M. E. P. from tests above made, less 8.5 per cent for friction as recommended by Henderson.

$R_2 = 0$ as the resistance is taken care of in the $P_2 C_1$ is the same as in the first case.

(3) $T.F. = P_1 C_1 - R_3$

$R_3 =$ Internal resistance taken from Henderson's formula $R_3 = 15V + C$.

The other quantities are as above stated.

(4) $T.F. = P_1 C_1 - R_4$.

$R_4 =$ Resistance of the machinery internal in the engine as determined by the "St. Louis tests."

(5) $T.F. = P_3 C_2$.

$P_3 =$ Available force taken from Henderson.

$C_2 =$ The "tangential factor."

On Plate VI is shown a typical comparison of the formula and test-car method. It appears that in service the theoretical tractive force for low speeds can hardly be expected. Further, since this is true, it is evident that the locomotive can produce more horsepower at about 15 miles per hour and thus also more ton-miles per hour. The factors are clearly indicated on Plate VII, in which the tractive force, tonnage rating and corresponding horsepower curves are shown. If a locomotive could produce the same horsepower at lower speeds the values would be much in excess of what they are found to be. This is evidenced by Plate VIII, on which "standard horsepower curves" are constructed, being simply "33,000 foot-pounds per minute" reduced to miles per hour and plotted. On this the tractive power of the locomotives have also been plotted and the result is that it is clear that the locomotives do not produce maximum tractive force until reaching a speed of about 15 miles per hour, above which it begins to reduce again slightly. It is the purpose of these figures to demonstrate the principle that tractive force is not a constant, nor a variable of regular variability, but that the curves are convex upwards until a speed of about 15 m. p. h. is reached and then become tangent to a curve of opposite flexure following approximately the cubical parabolas of the "standard H. P. curves."

V. Practical Rating.

Tonnage rating is not simply a matter of taking a maximum tractive power at a very low speed and dividing that by an arbitrary train-resistance constant. It is a science, and *adjustments for speed and temperature should be made after a careful study* with the full possession of data taken over the division in question upon the locomotives in question. It is finally established that there are too many factors entering into the making of a tonnage rating to use general averages as at all applicable for this important matter in economic operation and it is evident that there is a preventable loss where operation is based upon the old principle of "any old rating will do." Plate IX shows the "scientific operation chart" which indicates what speed the given locomotive can make with the given load, based on the careful study of all the factors mentioned above. A series of these charts were made and applied to the profile of the division in question and from these the ratings were established for the locomotives in use "to make the time required." The following is a sample of the tonnage table used:

Table IV.

Effective October 15, 1907.

Locomotive Nos.	Tonnage Trains North	Tonnage Trains South	Time freight tonnage, Train numbers: No. 21	No. 22	No. 23	No. 24	No. 27	No. 28
108-128	1,069	1,443	969	1,141	954	1,258	669	873
211-220	1,090	1,474	977	1,172	962	1,282	684	882
257-266	1,130	1,535	983	1,204	963	1,334	698	899
227-230	1,329	1,795	1,094	1,377	1,076	1,517	831	1,047
221-226	1,466	1,976	1,202	1,542	1,182	1,687	932	1,157
160-176	1,615	2,179	1,456	1,865	1,421	1,877	1,061	1,349
247-256	1,622	2,183	1,458	1,855	1,398	1,875	1,058	1,345
242-246	1,636	2,196	1,471	1,867	1,411	1,887	1,071	1,357

VI. Conclusions.

The adjustment of tonnage means a "stopping of leaks" where most needed. It reduces the big leaks in the coal pile, it reduces the high cost of repairs on both cars and locomotives, and most all it *produces* a spirit of satisfaction on the part of the engineers, who know they are not being required to perform a physical impossibility—namely, to haul maximum trains with engines not in first-class repair. The adjustments for temperature as recommended in the Bulletin No. 120 above referred to probably represent average conditions, but should be modified for any particular road by special tests and experience in operation. The reductions of tonnage for speed should also receive a scientific study and careful "service tests" should be made for the purpose. There have been found to be many "stock train" tonnages which were much lower than was necessary for the desired increase in speed.

Finally, since in the last analysis "the proof of the pudding is in the eating," it is interesting to note that after three years of operation on a "scientific basis" a superintendent of one of the roads entering Chicago has made the following statement in connection with the tests used herein as an example: "It has been a great improvement over the old rating and has been working out very nicely." Railroad men are not given to handing out bouquets promiscuously and it appears probable that there must be a reason for the success of the scientific tonnage rating.

RAILWAY CONSTRUCTION.

Work on the Sharon & Newcastle division of the Erie Railroad will begin within the next few weeks, it is reported. The work will be done by the Erie line and the tracks will be used by the Pittsburg & Lake Erie.

The Southern Ry. is going to carry out some double-track work north of Atlanta, Ga., for which contracts were recently let as follows: Lane Brothers Co., Altavista, Va., from Oakwood, Ga., to Buford, 11 miles; C. W. Lane & Co., Atlanta, from Buford to Suwanee, seven miles, also from Duluth to Pittman, three miles, and to M. M. Elkan, Macon, from Pittman to Cross Keys, 12 miles. The improvements include some grade and alignment revision.

The Minnesota, Dakota & Western is planning to build about 150 miles of extensions. The company now operates a freight line from International Falls, Minn., south, thence west to Loman, 23 miles; also 4.5 miles between International Falls and Falls Junction.

Official announcement is expected within a few days of the plans of the Evansville & Terre Haute Railroad for an extension 100 miles long from Evansville to Metropolis, Ill. F. P. Jeffries, general agent of the E. & T. H., and a party of Chicago officials and surveyors are making a tour of the proposed route in automobiles.

Locomotive Terminal and Shops, K. C., M. & O. Ry.

The Kansas City, Mexico & Orient Ry. will eventually form an important link between Kansas City, Texas and the Mexican Pacific coast by a route 1,659 miles in length, terminating at Topolobampo, Mexico. More than half of this, or 882 miles, is now constructed and in operation, 510 miles of which distance comprises the northern section between Wichita, Kansas, and San Angelo, Texas.

Being conveniently located for the purpose, the city of Wichita was selected as the seat of the principal locomotive and car repair shops for the northern end of this system, and comprehensive plans have been entered upon for developing here the principal facilities for rolling stock repairs which will be needed by the railroad when entirely completed and in operation.

A tract of land of some 760 acres has been secured, about three miles from the center of Wichita and adjacent to the main line of the railway. During the past year a large construction force has been engaged in creating here the beginnings of one of the largest railway repair shops in the Southwest. At the beginning of this development the railway officials retained Westinghouse, Church, Kerr & Co., to act as engineers and constructors, in order that their wide experience in the design of railroad repair shops might be brought to bear in laying out a permanent plant of such large dimensions.

The completed plant will comprise both the general repair shops and the locomotive terminal for this division of the road. The locomotive terminal will ultimately consist of a 40 stall roundhouse with an 80 ft. turntable, water tank, coal chutes, cinder pits and sand house. The locomotive shop, when ultimately completed, will be more than 500 feet long, and containing 20 erecting pits and will include the machine shop and the erecting shop, in parallel bays. Directly west of the locomotive shop there is to be a 75 foot transfer table with a runway about 630 feet long; and beyond this there is to be another building about 500 feet long, the northern portion of which will be the coach and paint shop, the southern portion to be used as the boiler shop. To the north of the roundhouse are the power station, the storehouse (with material platform around it), the foundry, the planing mill and the freight car repair shed, with lumber sheds and scrap bins conveniently located.

On the drawing showing the arrangements of the shops, will also be noted the freight yard on the side next to the main line, and to the northerly side of the plant is a generous sized repair yard.

The above-mentioned buildings are laid out to accommodate the repair facilities that will be required when the completed railway is in operation. In the meantime, even with the incomplete operating mileage, an impressive beginning has been made upon most of the buildings that will ultimately constitute the plant. The buildings so far erected are mostly of sufficient capacity only for initial needs; but each one is so built and located that its enlargement can readily be effected along predetermined lines that will ultimately fill in the prearranged plan herewith presented.

The site selected is on the prairie about a mile from the Arkansas River. The soil is alluvial sand, and because of the low elevation above the Arkansas River it is well saturated most of the time, so that the foundation and drainage problems called for especially careful treatment, 1,500 lbs. per square foot being the maximum permissible loading.

The locomotive terminal installed for present needs includes a 10-stall roundhouse with an 80-foot turntable, a 12-pocket coaling station, a sand house, a 160,000-gallon water tank, and a cinder pit.

The repair facilities which have been provided at this time, consist of a locomotive repair shop building that includes a boiler and blacksmith shop, machine shop and erecting shop; a power station for supplying power, light, heat and compressed air; a coach repair and paint shop, a storehouse, planing mill, and two sheds for storing rough and finished lumber; also, an oil house, a pump house for the water supply system and three hose houses. Besides the required piping systems for distributing the water, air and heating services to the various buildings, there are also inter-communicating tracks between the shops, with industrial turntables at intersecting points.

The roundhouse is laid out for 10 stalls and is so disposed that 30 more stalls can be added when required. It is located far enough from the main line track to allow room for a freight yard of 8 tracks, when the full circle of the roundhouse is completed. The roundhouse walls are of brick with a wooden roof supported on timber posts. The roof girders are single sticks of 8 x 16 yellow pine from 20 to 26½ feet between the points of support. The roof is nearly flat and is of wood sheathing with 4-ply tar and gravel covering. The building foundations consist of rectangular concrete footings under the posts and the pilasters of the outer walls. The end walls of the roundhouse are carried on a continuous concrete footing about 4 ft. wide. In each stall there is a pit 61 feet long built of reinforced concrete resting upon a reinforced concrete mat foundation extended to an extreme width of about 10 feet. The concrete pit side walls are 2 feet thick. The track rail rests upon one 8x12 stringer and alongside it is a separate 12x12 jacking stringer. Two stalls are fitted with driving wheel drop pits while the

General View of Wichita Shops, Kansas City, Mexico & Orient Ry.

third one from the south end is fitted with a truck drop pit. All the drop pits are built of reinforced concrete and are fitted with hinged rails.

The tracks enter the building through double leaf doors 14 feet wide in the clear between posts. The rear of the roundhouse is well lighted as the windows take up the full width of the space between pilasters and run nearly to the eaves. The smoke-jacks are built of asbestos lumber.

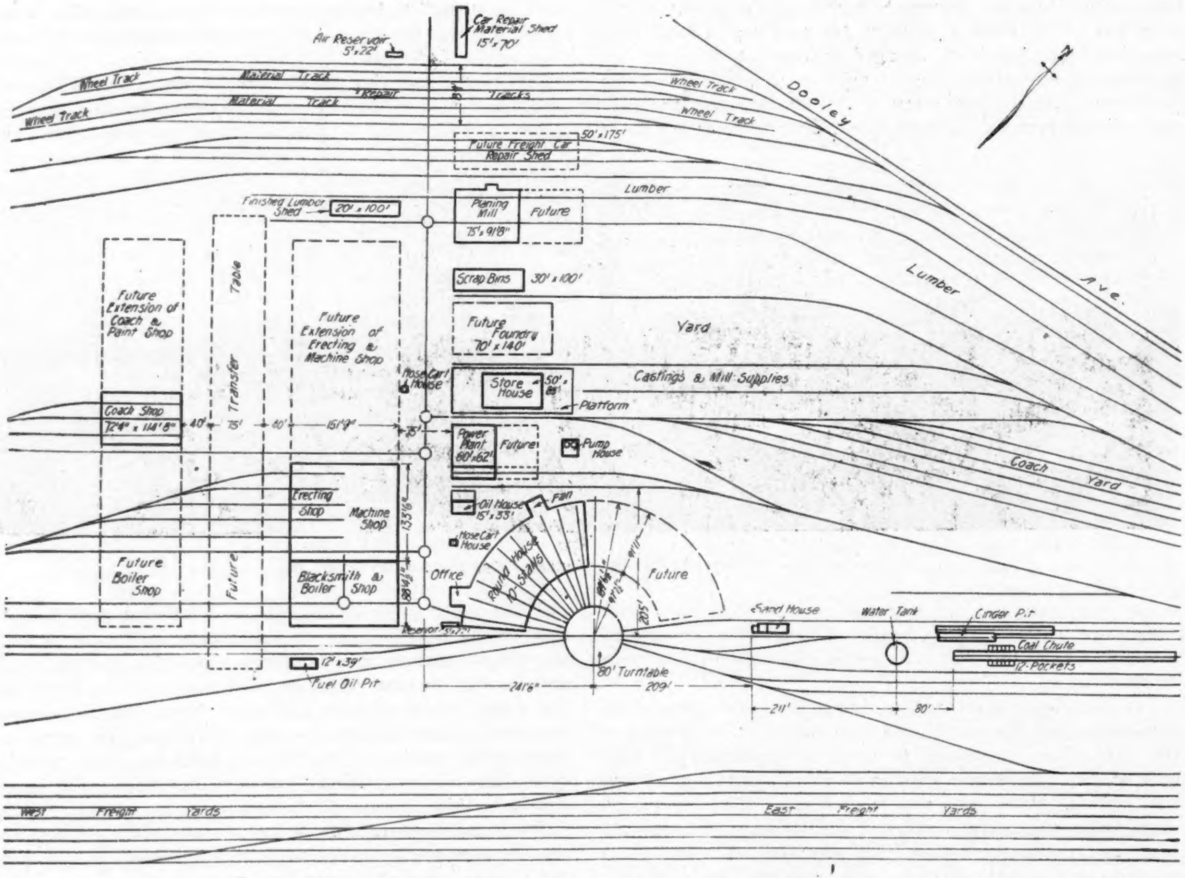
The roundhouse is supplied with steam, water and air service. The house is heated by the indirect fan system, using exhaust steam, the fan being located in a small brick addition whence air is forced into a system of concrete and tile ducts in the roundhouse floor radiating to the various pits. The capacity of the fan is sufficient to change the air in the roundhouse once every 10 minutes.

Live steam is supplied to the roundhouse for blowing up cult and a shallow turntable pit is therefore desirable. Accordingly the through type of table was selected, which required a pit but 3½ feet below grade. The central foundation is a slab of concrete 22 feet square and 3 feet 5 inches thick reinforced by 1⅛-inch round rods. The ring wall foundation is an annular slab of reinforced concrete 13½ feet wide across the bottom, 7 feet wide at the rail base and brought up to form a pit wall 2 feet thick.

Besides having two independent connections to the main line and yard tracks, the turntable has three separate tracks leading past the cinder pit, sand house, coal chute and water tank, so disposed that two locomotives can be simultaneously served at each of these points. There is also an independent track from the turntable to the repair shop.

Coal Pocket.

For coaling locomotives a timber trestle is located in the



General Layout, Wichita Shops, Kansas City, Mexico & Orient Ry.

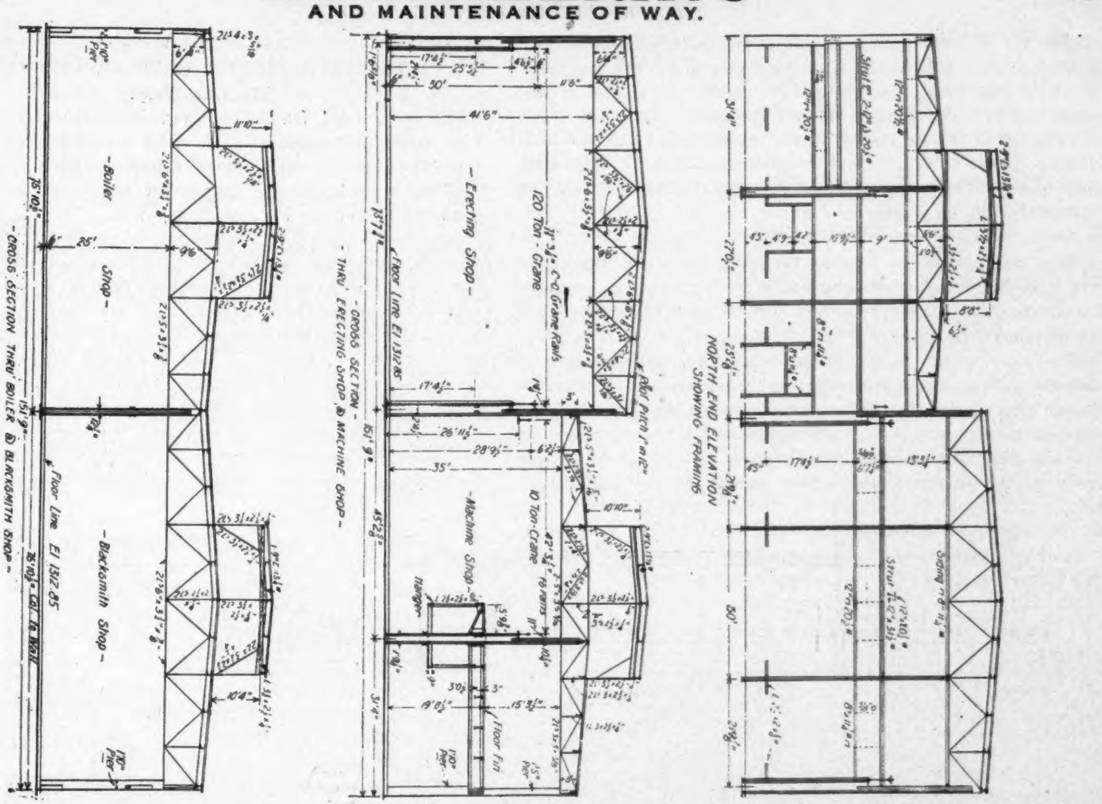
locomotive fires through a 1½-inch connection at each stall. A 1½-inch water line is brought to each stall for boiler washing. For pneumatic tools, flue cleaning, etc., compressed air service is piped from the power station with a connection from each stall. The artificial lighting of the roundhouse is by means of 9 3-light clusters of 16 c.p. lamps and 33 single 32 c.p. lamps. Wall plugs are distributed about the pits and on the walls and posts for extension lamp cord connections.

At the southwest corner of the roundhouse is a one-story addition divided into four rooms, which include a wash room and a toilet room for the men, and two rooms for the foreman's office.

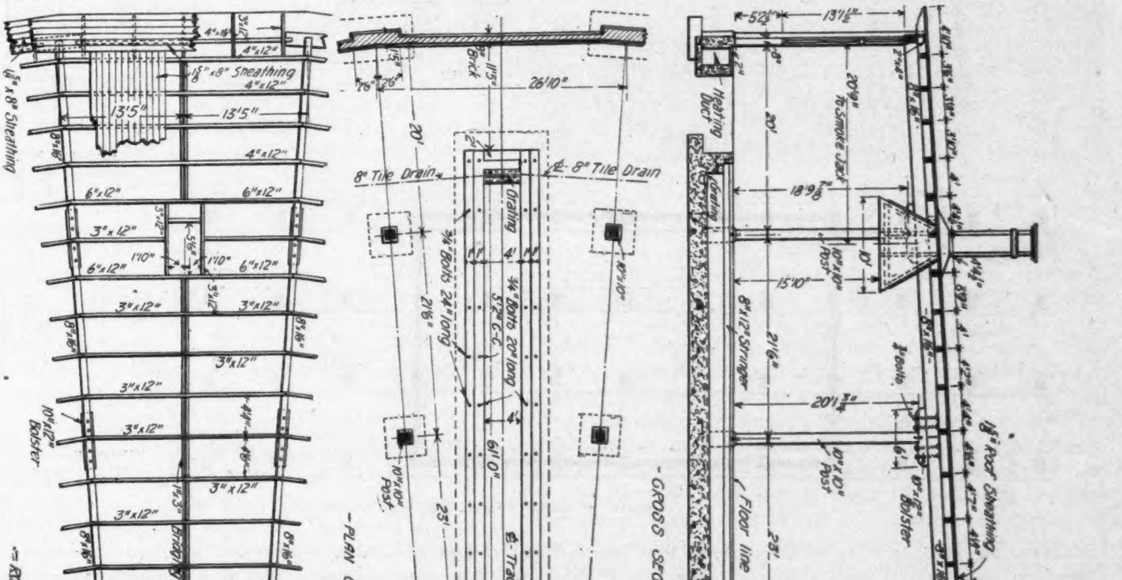
The roundhouse is served by an 80-foot turntable. The low level of the terminal site makes natural drainage diffi- center of the locomotive terminal yard east of the roundhouse. There are 6 side dump pockets on each side of the central coal track, lined with steel plate and fitted with the Williams-White dump gate and chute. Each of the 12 pockets is of about 4 tons capacity.

Cinder Pit.

On the track north of the coal pocket is the cinder pit. On account of the difficult drainage and soft soil this was also of somewhat special design. There is a single track slightly elevated, one rail resting on wooden blocks set in a concrete stringer about 5 feet deep, the other on a 15-inch I beam carried on concrete posts, and the whole supported on a reinforced concrete mattress 15 feet wide and 8 inches thick, the bottom of the mat being about 4 feet below grade while the rails of the track are about two feet above grade. The



Construction of General Shop Building.



Round House Construction, Wichita Shops.

cinder pit is brick paved on a cinder bottom and is only 6 to 9 inches below the ground level. The ash car spur track is depressed 3½ feet below ground level and is approached by a 5 per cent grade. Drainage of the ash track depression is to the regular sewer system, through a 6-inch drain. The cinder pit will be duplicated on the opposite side of the depressed track in the future enlargement of the terminal.

Water Tank.

The water tank is located between the same tracks as the coal chute and is designed to serve both for the locomotive supply, and as a reservoir for the entire terminal and shop plant.

The tank is of steel 26½ feet diameter, 40 feet high, of 160,000 gallons capacity and rests on a reinforced concrete base. The locomotive water supply is drawn from a level 20 feet below the top leaving the lower 20 feet as reservoir capacity for the water supply system of the plant. There are two locomotive tank water spouts of the usual type mounted on opposite sides of the tank, so that two locomotives can take water simultaneously. The top of the tank is fitted with a wooden roof to diminish freezing from the top in winter. The water level is maintained within the desired limits by a float-operated electrical switching device which controls the electric driven pumps in the well house, that supply the tank.

Sand House.

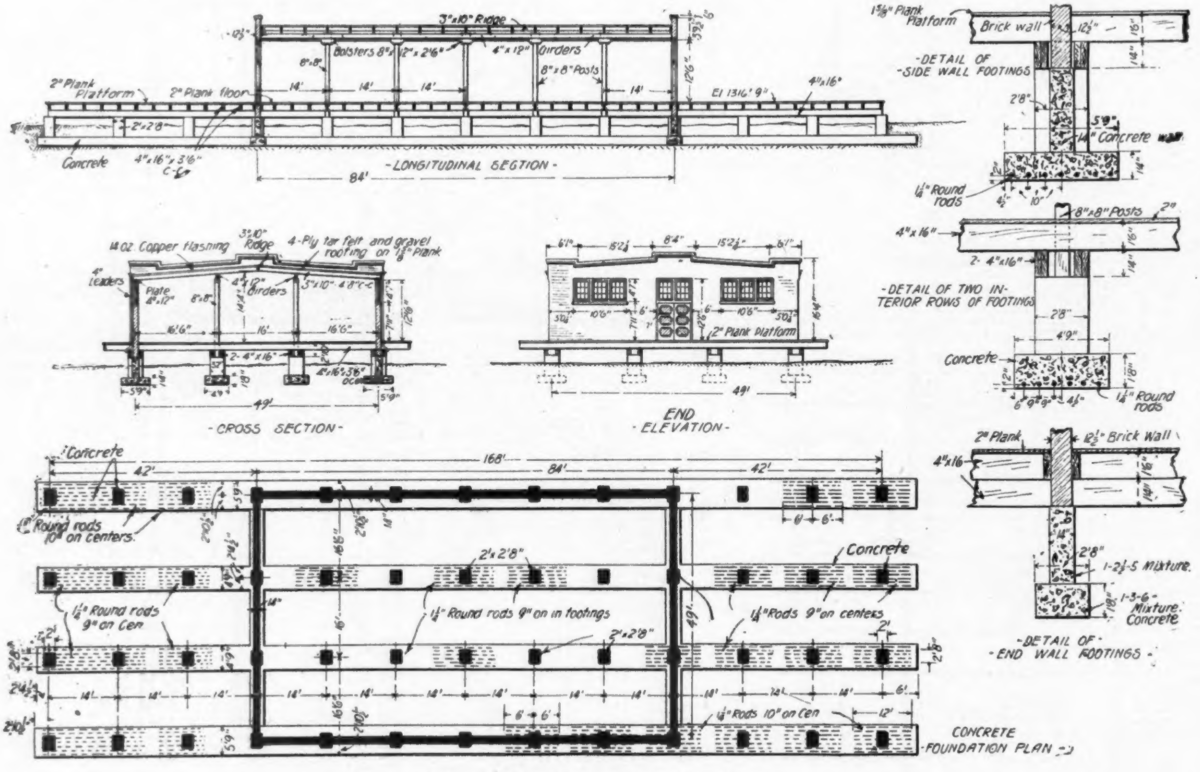
The sand house is between the water tank and the turntable and is of timber construction, comprising a receiving bin, a drying room, a screen, an air lift and an elevated bin for distributing dried sand to locomotives. The sand stove is located adjacent to the end of the bin. After being run through the stove and screened, the sand drops into a steel tank in the base of the tower from which it is lifted by air pressure to the elevated bin in the top of the tower, whence it is distributed to locomotives by the usual spouts.

Machine Shop.

This is a steel frame building, about 152x220 feet with brick walls and wooden roof. The erecting shop and machine shop are in three parallel bays, with the boiler and blacksmith shop running across the south end of both and separated therefrom by a brick fire wall. The machine shop foundations consist of continuous reinforced concrete slab footings, under the bases of the building columns, and the side walls, also under the cross wall dividing the blacksmith from the machine shop portion. The erecting shop pit foundations are 46 feet by 10 feet reinforced concrete slabs. The pit walls are of concrete 2 feet thick and capped by 8-inch timber stringers. The bottom of each pit is sloped to a sump, which discharges into the drainage system.

The erecting shop is 132 x 76 feet, and accommodates six pit tracks with separate entrances through the west wall of the building. The clear height of the roof trusses above the floor is 41 feet 6 inches. The shop is designed for a 120-ton traveling crane, the span between centers of the crane rail being 71 feet 3¼ inches. The crane runways are supported on steel columns. The roof is very slightly pitched and is without a monitor. The upper tier of windows on the west wall runs up practically to the eaves, providing ample light for the entire floor space. The side walls are of brick in the lower story, the upper portion of plaster on special galvanized expanded metal. There is a double swinging door for each track entrance with a transom light over each one of them.

The machine shop is built in two longitudinal sections, that over the heavy machine floor being served by a 10-ton traveling crane running the entire length of the shop over the large tools, the other section having a gallery running its full length, and without crane service. There is a small



Details of Store House, Wichita Shops.

mezzanine gallery at each end of the latter, one containing a foreman's office and the other the men's lockers and lavatory. The machine shop has a monitor roof 10 feet high over its entire length and all the space between pilasters between the east wall of the building is given up to windows in both stories of the gallery.

Boiler and Blacksmith Shop.

The boiler and blacksmith shop is of but one story with deep roof trusses, there being a monitor roof 10 feet high over each shop. There are two tiers of windows around the three sides of the boiler and blacksmith shop so that the entire floor space is well lighted. The building is heated by an indirect fan system using exhaust steam.

The artificial lighting of the main shop is accomplished primarily by 23 type P 700 c.p. Cooper-Hewitt lamps and 18 type H 300 c.p. Cooper-Hewitt lamps, supplemented by a number of incandescent lamps run from wall plugs on the walls, columns and pits.

Water service is taken to a 2½-inch connection in each erection pit for boiler washing, and there are the usual lavatory and toilet facilities. At each pit there are also two air connections for pneumatic tools. The 4-inch steam line runs through the whole length of the building to the blacksmith shop to supply the steam hammers, and branches are provided to suitable outlets to the boilers and erecting shops for boiler testing. All the windows in the building are opened and closed by sash operating devices.

A portion of the machine tools in this shop are those formerly in use in another shop, and a number of modern ones were added for present needs. They are mostly operated from direct current constant speed electric motors by group drives. The driving wheel lathe is driven by a separate variable speed motor. Other motor driven machine tools are later to be added to the equipment.

Due consideration was given to the merits of both the alternating and direct current systems for operating these shops, but the fact that direct current is necessary for the proper control of variable speed machine tools, the undesirability of having two systems in the present installation, and the general nearness of the shops to the power station, all influenced the decision in favor of direct current on the 220-volt 3-wire system.

There are five group drive motors, two being of 40 H.P., two 25 H. P. and one 13 H. P., all of the 200-volt open type.

The tool room is at the north end of the machine shop directly under the foreman's office. The future extension of the building will be toward the north and will bring the foreman's office near the center.

Power House.

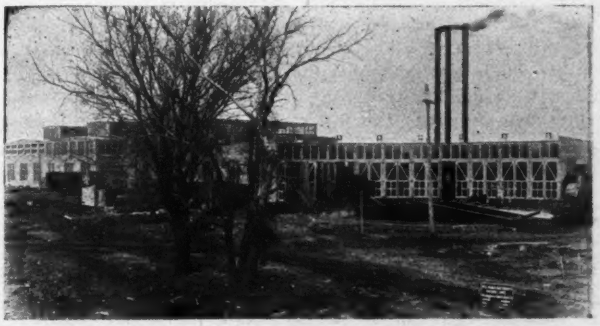
The power house is a brick and concrete building with steel roof beams, 60 x 62 feet and about 25 feet high. There is no basement, except for the pipe tunnel or subway across the side of the engine room, in which most of the service steam and exhaust pipe lines running to the outlying buildings are carried to the main pipe tunnel outside. The walls are of brick and the roof is a reinforced concrete slab supported on 20-inch 65-lb I beams, and waterproofed with 4-ply felt and gravel roofing. Alongside the boiler room is an elevated coal track carried on concrete piers from which coal is dumped into a bin underneath that opens directly into the firing floor.

The equipment of the power house consists of three Stirling water-tube boilers of 184 H.P. each, hand fired, and with individual guyed stacks; space remaining for an additional boiler.

There are two boiler feed pumps and one 900 H.P. feed water heater large enough to provide for the future as well as the present installation. In the engine room there are two generating units of 150 Kw. and 75 Kw. respectively, direct connected to compound engines. Space is provided for an additional engine. The generators are of the Westinghouse 3-wire, 110 and 220 volt D. C. type with balancing coils. There is also a 1,000 cubic foot compound steam 2-stage air compressor of Ingersoll-Rand make. A 4-panel switchboard controls the electrical distribution through the buildings on the three-wire system. The power house is lighted by 72 16 c.p. incandescent lamps. There is room in the power station for such increase of power station equipment as may be needed by the gradual enlargement of the repair shops in the near future.

Oil House.

Between the roundhouse and the power station is the oil house. This is also a completely fireproof structure of brick and reinforced concrete, resting on a concrete slab foundation and comprising also a concrete platform with extended storage vault space beneath it and outside of the oil house proper. The basement accommodates cylindrical steel oil tanks mostly of 700-gallons capacity each, for the various oils and lubricants. For distributing the oil there is provided a Bowser system of self-measuring oil pumps and indicators. For fire protection a 4-inch hose connection is conveniently located on the main floor. The building is heated by steam coils supplied by the exhaust steam heating line from the adjacent power station.



Exterior of Round House and General Shop.

Storehouse.

The next building to the north of the power station is the storehouse. This is a one-story brick building with concrete foundations, plank floor and roof construction, the roof being carried on a double row of timber posts. The building is 84x49 feet and is entirely surrounded by a loading platform which is about 6 inches wide on both long sides of the building and so extended lengthwise as to cover an area of about 42 x 62 feet beyond each end. The foundation of the entire storehouse and platform consists of four parallel reinforced concrete footings 178 feet long and 16½ feet apart. The end walls of the building are carried by two similar reinforced concrete footings at right angles to the former. The building piers are spaced about 14 feet apart lengthwise of the building and are at an elevation suitable for convenient loading and unloading merchandise from freight cars. The roof covering is of 4-ply tar and gravel. There is an office and supply counter in one corner. The office windows are 8 feet high and fitted with double hung sash, while those in the warehouse space are but 4 feet high with sills 8 feet above the floor all around the building. The entire floor area of the storehouse and platforms is designed to carry a live loading of 275 lbs. per square foot. The building is warmed by the direct system, using exhaust steam from the adjacent power station, and lighted by 32 incandescent lamps. Two hose valves with hose are installed for fire protection.

Coach and Paint Shop.

This building is so located to the northwest of the loco-

motive repair shop that both this department and the locomotive repair shop will eventually be served by the same transfer table when future operations may warrant its installation. Like the locomotive shop, only the initial bays of the building are now installed and the north wall is of timber construction so as to admit of economical extension of the plant whenever required. At present the building consists of three bays each 20 feet wide with storage space 8 feet wide across one end, the present outside dimensions being 115 x 74 feet.

The building is of simple construction, comprising brick walls with high windows and swinging doors in both side walls for the three coach tracks which pass through it. The roof is of plank with tar and gravel waterproofing supported on timber posts and is provided with six skylights of ample size. The posts are spaced 16 feet apart in line forming 20-foot bays. By reason of the light loading the foundations consist simply of individual concrete footings 4 feet wide under the walls and 4 feet square under each post. The building is heated with a direct system of steam pipe coils.

Water service is provided for washing the coaches and sash, and compressed air for testing air brake, air cleaning and operating air tools. Fire protection is supplied by two 2½-inch hose connections.

Planing Mill.

Beyond the storehouse and scrap bins is located the planing mill. This is a brick building 94 x 78, one story high with a single row of timber posts down the center supporting a wide monitor-type roof on wooden trusses. Like the other shop buildings, this is arranged for future enlargement, which will be toward the east. Consequently, the present east wall is temporary and made of timber construction.

The brick walls are carried on concrete footings 4 feet wide and the center posts on separate footings 5 feet 3 inches square. The main windows are about 10 x 16 feet and four swinging doors are arranged to accommodate two railroad tracks completely through the building. A small addition is built on one side to accommodate toilet and lavatory facilities. The building is heated by the direct system using exhaust steam from the power house, and artificial light is supplied by six Type E Cooper-Hewitt lamps. Live steam service is also introduced for heating glue pots, and compressed air service is piped into the building.

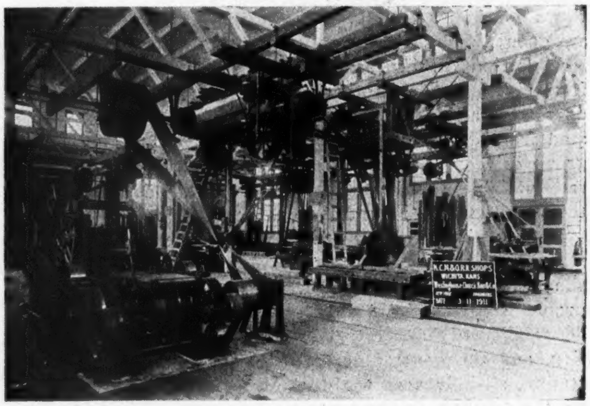
The planing mill is fitted with a number of new tools, among which may be mentioned a 14 inch x 20 inch timber sizer, a 24-inch pattern maker's lathe, a 4-spindle wood borer, a 6 x 14 moulder, a 2-spindle shaper, a jig saw, combination saw, a 24-inch pony planer, a self-feeding rip saw, and a cabinet mortiser and borer, besides a complete outfit of saw and knife grinding machinery, benches and vises. Several old tools from another shop are also used. The tools are belted to two line shafts run by separate D.C. motor of 40 and 50 H. P. respectively, the line shafting being carried on the roof trusses. Fire protection is supplied by two hose valves within the building.

Lumber Sheds.

Beyond the planing mill, space is reserved for a future freight car repair shop, and beyond, across the repair yard tracks is a one-story car repair material shed of timber construction. Directly across the main thoroughfare from the planing mill is another shed for storing finished lumber for car repairs.

Water Supply.

One of the most important features of a locomotive terminal is the water supply. Directly east of the power house is located the well house, which incloses two wells about 55 feet deep, bored down into water bearing sand, that tap an ample supply of excellent water, noticeably of better quality for boiler use than that obtained directly from the river. The natural level of the water in these wells is but 5 or 6 feet below the surface and they are able to supply more than 300 gallons per minute each. They are fitted with reinforced concrete casings all the way down, having openings in the lower sections only, to admit water. The well house is a one-story fireproof structure of brick and concrete, 19x20 feet, with basement about 5 feet deep and pump pit extending about 7 feet below the ground level, the whole structure being on a solid concrete slab foundation. Over the top of each well casing there is a centrifugal pump run by a 15 H. P. Westinghouse motor set directly over it. Each pump has a capacity of about 150 gallons per minute and delivers water into the 10-inch main running to the bottom of the 160,000-gallon water tank, previously described, which performs the double function of reservoir and locomotive supply tank. The pressure in the distributing system to the service piping and fire hydrants is ordinarily maintained by a 400-gallon steam service pump located in the roundhouse fan room, which maintains a pressure of about 100 pounds on the distributing system and the boiler washing line in the roundhouse. This pump is supplemented by an Underwriter's fire pump of 750-gallons capacity located in the well house. Both these pumps draw from the 10-inch main and discharge into the general distribution system and can thus supply a maximum on emergency of 1,150 gallons per minute. The distributing main is 8 inches, reduced to 6 inches at extremities and extending the full length of the main thoroughfare between buildings, with lateral extensions covering the entire property. Besides the hose valves already noted in the buildings, there are 17 out-door hydrants distributed over the property and water service connections are extended into the coach yard track for washing coaches. There are three hose houses conveniently located about the property, each containing a supply of fire hose mounted on hose carts.



Interior of Planing Mill.

Air Supply.

From the air compressor in the power station, compressed air is conducted through mains of 3 inches down to 1½ inches diameter, to all the shop buildings, the sand house and into the coach yard, also to the sewer air lift and to the fuel oil tank. Eventually this service will be extended into the freight yard. An equalizing air reservoir is located at the end of the main in the freight car repair yard.

Electrical Distribution.

The yard tracks are illuminated by 19 Westinghouse carbon D. C. arc lamps on the parallel system at 110 volts. They are mounted upon pole top fixtures upon wooden poles. All distribution of electric current to the lamps and buildings is by overhead wires. Within the shop buildings the electric supply main conductors are generally run open,

being supported on the roof trusses, while the branches to motors, lamp circuits and wall and pit connection plugs are mostly inclosed in conduit, many of them running under the floors.

Drainage System.

The Arkansas River is a mile distant and at times of high water drainage by gravity through the usual arrangement of sewer connections would be impracticable. The main sewerage system of the buildings is constructed of vitrified tile in the usual manner and connects with the city system of Wichita, but in order to compel the outward discharge of drainage into the main sewer when flooded, a sewer lift was placed at a convenient point in the yard which receives the entire out-flow from the yard and buildings, and by means of an air lift elevates it so as to provide an artificial head of about 7 ft. that will insure discharge into the city sewer under any flood conditions. The sewer lift is a 3-chambered pit with gate valves connected in such a way as to practically form a 3-way cock. With the valves open one way the sewage flows from the receiving pit to the discharge and thence to the outgoing sewer by gravity. With valves open the other way, and with two air lifts of 300 gallons capacity each per minute brought into action, the sewage is elevated from the receiving pit to the 7-foot level in the discharge pit. The roof drainage is handled separately into the discharge pit without being air-lifted, as there is no objection to the water backing up in roof conductor pipes because they are kept separate from the other sewer connections of the buildings. The sewerage system is constructed of 6 and 8-in. connections from the buildings, to 10, 15 and 24-in. main sewers and includes a number of brick catch basins and manholes besides the sewer air lift pit above described.

Fuel Oil Supply.

At the south end of the locomotive repair shop building in a concrete vault is a cylindrical steel tank for fuel oil which is used at the furnaces in the blacksmith and boiler shops, and also to the roundhouse where it is used for lighting fires.

Pipe Tunnel.

Between the power station, the locomotive repair shop, and the roundhouse, the aggregation of important main pipe lines for live and exhaust steam, air and water service made it desirable to construct a pipe tunnel for properly protecting them, especially on account of the exhaust steam heating system used in the roundhouse and locomotive and repair shop. In this tunnel are run the exhaust steam, live steam outgoing and return pipes, and air piping. The tunnel is about 4 ft. wide, from 4 to 6 ft. deep and is built with concrete walls and roof. There are about 270 lineal feet of subway and access to it is had through a number of conveniently arranged openings.

The construction work was begun in May, 1910. The principal buildings were completely inclosed by November, the equipment promptly installed, and the entire locomotive terminal and shop equipment are now in full operation. The development above described was carried out by Westinghouse, Church, Kerr & Co., under the direction of E. Dickinson, vice-president and general manager; F. Mertsheimer, general superintendent motive power and car department; W. W Colpitts, chief engineer, and A. H. Dickinson, superintendent. Master Mechanic David Paterson is in charge of the operation of the shop.

The Signal Department

RAILWAY SIGNAL STANDARDS, NO. 19, THE CHICAGO & ALTON.

The first installation of automatic signals on the Chicago & Alton was about 1900. The signals are of the upper quadrant type, the blades having two positions only, with a stroke of 60 degrees. Both the normal clear and normal danger signals are in use. The night color indications are green for clear, yellow for caution, and red for stop. The signals are semaphore type, operated by electro-motor at the bottom of the post. Batteries are housed either in concrete wells, or in iron chutes. Gravity or potash batteries furnish the current for operating signals, and the same battery is used for line circuits and for signal operations. Two and sometimes three cells are used in the gravity battery. Direct current only is used. The track circuits have overlaps and do not exceed 3,000 feet. Relays have a resistance of 4 ohms, and are Hall, Union, or General Electric type. Separate pole lines are not used for signal circuits; line wire is No. 10 copper clad. Common return is broken every 5 miles. Wire ducts are wooden, and are above ground. No. 8 copper wire is used for bootlegs, No. 9 is used for leads from tracks and leads from line are No. 12 or No. 14.

Switch indicators are upper quadrant semaphore type, not illuminated at night. Bracket posts are permissable where conditions are favorable.

The Chicago & Alton is adopting the Railway Signal Association standard plans and specifications. (Figs. 7 to 22, Railway Engineering and Maintenance of Way, January, 1910.)

SIGNALING ON THE ATLANTIC COAST LINE.

In December, 1910, the Atlantic Coast Line R. R. placed in service on their main line between Florence, S. C., and Pee Dee, S. C., a modern automatic block system, together with electro-mechanical interlocking plants at the north end of Florence yard, North end double track, at Pee Dee draw and Pee Dee junction; they also installed the electric train staff system on single track between the north end of double track and Pee Dee junction. The section consists of ten miles of double track and two and one-half miles of single track. The single track extends over the Pee Dee river drawbridge and steel viaduct, which is two miles long, and was recently built to replace a wooden trestle of the same length.

The automatic and main line interlocking home signals are of the Union style "S" upper quadrant type, operated in three positions. All automatic signals are equipped with one light, one pointed end blade and a number plate. All interlocking home signals are equipped with two square end blades and two lights; the top arm governing main line movements, and the bottom arm diverging movements, or where there are no diverging movements, the blade is fixed.

The automatic signals on double track are controlled by polarized track circuits, and those on single track are controlled by straight line and polarized line circuits. The signals on the single track section are operated similar to those on other single track roads employing automatic signals, except that they are arranged for the protection of following movements only.

The average track circuit on the double track is about five thousand feet, and on single track about three thousand five hundred feet, and is operated by two cells of bluestone battery connected in multiple. In most all cases the automatic block signals are located directly opposite each other, and are operated by a bank of eighteen cells of BSCO 400 A. H. battery, nine cells being located in the battery section of

each signal case, and all connected in series. Numbers on the number plates are made of enameled iron and are six inches high, and attached to the number plates with four one-quarter inch bolts.

The interlocking plants are of the type known as electro-mechanical, operated partly by electrical and partly by mechanical means. All interlocking functions except main line power operated signals are operated with one-inch extra heavy iron pipe galvanized. All main line interlocking signals are semi-automatic, the movement from stop to caution (forty-five degrees) being controlled by track circuits and electric lever which is interlocked with the mechanical levers of the interlocking machine. The movement from forty-five degrees, "caution," to ninety degrees, "clear," is automatic and governed by indication of first signal in advance. Should the automatic block signal in advance of the interlocking home signal indicate stop, when towerman throws the electric lever to clear the home signal it will clear to the "caution" position only, but as soon as the block signal in advance changes from "stop" to "caution" or "proceed" the home signal moves to ninety degrees automatically.

The interlocking at Pee Dee drawbridge consists of four mechanical and two electrical levers; the four mechanical levers operate two eight-way electric bridge circuit controllers, four lift rail locks and two smash boards; the latter being operated through the agency of the Johnson type bridge couplers. The drawbridge home signals operate the same as the automatic signals, except that the circuits are controlled through the electric levers of the interlocking machine and through circuit controllers on the smash boards which are located on the home signal poles.

All interlocking towers are provided with electric semaphore indicators which inform the towermen when trains are approaching their towers on the main tracks.

Approach locking makes it impossible to change the route in front of an approaching train after signal has been accepted by the engineman, except by operating an emergency releasing instrument which requires sufficient time to permit an approaching train to pass through the limits of the plant or come to a full stop; also it is impossible to change the route, or set up any conflicting route until all signals have assumed their proper stop indications, thus eliminating the chances of an accident due to the engineers on following trains accepting false "clear" indications.

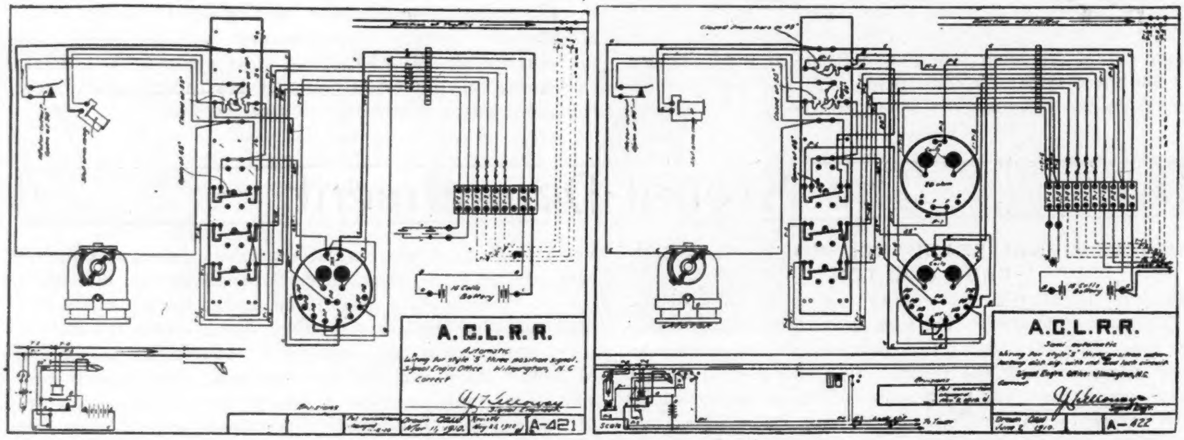
In order to make the capacity of the single track equal to that of the double track in one direction it was necessary to guard against opposing train movements without train orders. In order to accomplish this feature without complicating the signal system, the electric train staff was used. The staff system consists of staff instruments erected in the interlocking towers at Pee Dee junction and north end of double track, electrically connected. A staff cannot be withdrawn from an instrument without the knowledge and co-operation of the signalman in charge of the other; and when a staff is withdrawn from one instrument, another cannot be withdrawn from either instrument until the staff already withdrawn is replaced in the same instrument, or in the one at the other end of the block.

To move a train over the single track section, the signalman must first procure a staff, and then insert it in the ring staff pouch, and place the pouch in the staff crane deliverer, to be caught by the engineman of the train about to enter the block. The engineman will not enter the block until the staff, or a section of a staff, is in his possession, which is authority for his train to proceed against opposing trains. The staff is caught by the engineman at regular speed. It is understood that the engineman is governed by the automatic signal indications while moving over the single track the same as if he were on double track.

The system is operated in the usual way, except that all staffs are of the divisible type; i. e., each staff may be divided into five parts, making it possible to send five trains over the single track on one staff. When more than one train is to be moved in the same direction the dispatcher instructs the signalman the number of sections into which the staff is to be divided, and a section is delivered to the engineman of each train about to enter the block, and sections are delivered to the signalman at the other end of the block in the same manner as the complete staff would be.

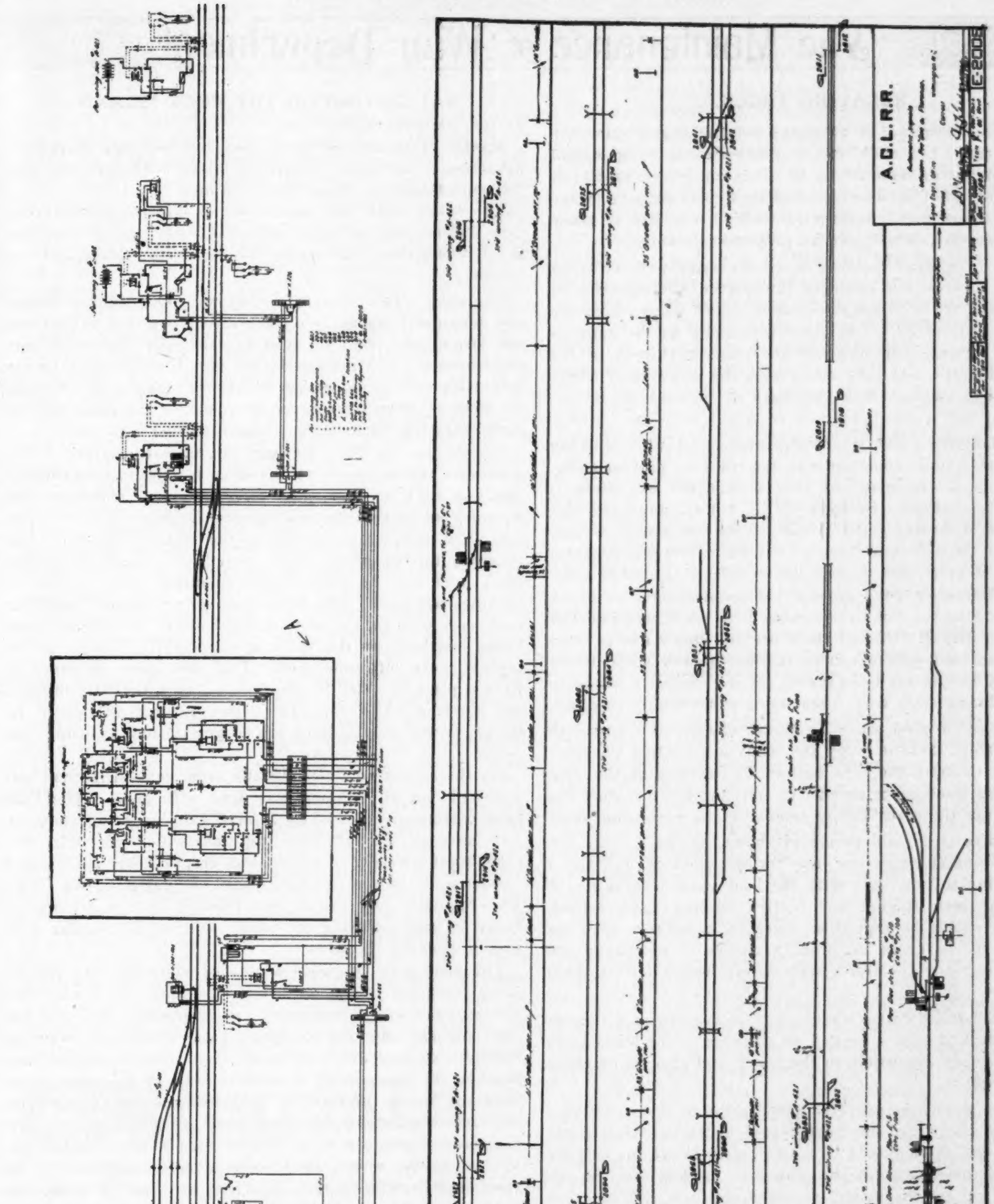
The interlocking signals which control movements to the single track are controlled by circuit controllers on the staff crane deliverers in such a way that the signals cannot be cleared until the ring which contains the staff is hung in the deliverer.

All rubber covered wires, pipe, glass, bond wires, pipe carrier foundations and concrete foundations are in accordance with Railway Signal Association specifications. Plans and details for the installation were worked out by Mr. C. J. Kelloway, Signal Engineer of the A. C. L. The work was installed by the A. C. L. Signal Department forces.



Wiring for Three-Position Distant Signal, A. C. L. R. R.

Grant, Smith & Co., Spokane, Wash., have started work on the Kootenay & Alberta, from a point one mile west of Pincher, Ala. The work will be heavy. The line is being built to carry coal from the Western Coal & Coke Company's mines. L. B. Merriam, chief engineer, 125 Phoenix building, Winnipeg.



Automatic Signal Layout Between Pee Dee Jct. and Florence, A. C. L. R. R. Tower and Track Circuits Illustrated Above.

The Maintenance of Way Department

RELAYING TRACK.

I am no admirer of large gangs in gang organization for relaying rail. For 85-lb. rail and heavier the gang should be constituted of from 35 to 40 men, and under 85-lb. rail 30 to 34 men. This does not include two flagmen, a water boy and straw boss. A foreman with 40 men has as many men as one man should have for proper supervision.

I prefer the straw boss to be of the same nationality as the gang and do not favor an interpreter; the majority of interpreters are a criminal nuisance. The reason I prefer the staw boss to be of the same nationality as the gang, is that the foreman can pick out the most intelligent of the men to do little odd jobs along with the straw boss where the foreman cannot leave the body of men to do it personally.

As to relaying a rail, the most prominent method is to lay one rail at a time, coupling it in the track as you go along. The principal argument for this is that the expansion is better taken care of. Personally I do not see any particular difference in stringing the rail or laying one rail at a time, any more than that a foreman can more readily organize his gang if he strings the rail and couples it up, while waiting for trains. I have got just as good results as to ex pansion on laying rail by stringing it as by laying one rail at a time. On all divisions there are dull hours due to train movements, and where a man strings the rail while trains are thick, he can set rail up and get it coupled in shape to relay it during slack time when trains won't bother so much.

On the other hand, when laying rail one rail at a time with foreign labor, there is many and many a joint that the foreman has to start the first bolt in on account of the men not having intelligence enough to start the bolt or apply the bar and get tightened before removing the expansion shim.

The foreman should divide his gang, having a few men ahead pulling spikes, a few men throwing out old rail and a few putting in new rails with the lead spikers nailing it in place, the men spiking and bolting coming right behind. The men should be kept close together, in order to give the foreman in charge of the work a chance to personally see that he is ready for trains with safety before letting them over.

All rail laid on curves should be laid one rail at a time as a great deal of care is needed on the part of the foreman to get the proper expansion on the curve, and also approaching and leaving it.

All ties should be properly adzed prior to laying rail and then before new rail has been placed in track, after old rail is taken out, there should be a small strip about one-half the width of the base that the old rail marked on the tie trimmed off on the inside, so when the new rail takes its position that trains will give full polish on the entire width of the ball of the rail.

It is a shame to lay new rail and note after the first train that passes over it that the wheels have a bearing only on a narrow strip on one side as shown by the mark on the ball. This is a defect and should be remedied immediately, for after it is allowed to remain for a short time in this manner, you can never get good surface nor a good line on that piece of track.

There should be a sufficient number of joint ties spaced and slot spiked to guarantee holding expansion, until the surfacing gang gets the track properly surfaced and spaces all the ties.

Roadmaster, Santa Fe.

BALLASTING ON THE ROCK ISLAND.

Editor, Railway Engineering:

Several years ago the writer used the following method in ballasting a section of the Rock Island with crushed rock, the gang numbered from 150 to 200 men.

The entire track was raised out of face or brought to a new surface, and 12 inches of new crushed rock ballast put in. Grade stakes were set by the engineers at each 100-foot station.

The gang was organized as follows: One gang foreman, one assistant foreman, one track raiser, one time-keeper and one straw boss, who received 25 cents per day more than the laborers. The raising on the first lift was done by six men with two jacks, except when the gang was crowding the men or when opening up the work in the morning. At such times four jacks were brought into service.

The ballast on first lift was run in with shovels. The men were spaced two in 15 feet when blading in with shovels, and one each 15 feet when pick tamping. Sufficient men were placed outside the track to cast in ballast for the tampers. The gang was followed by the straw boss, with 15 or 20 men, raising places that settled, and lining; thus the track was left in fairly good condition for a speed of 40 miles per hour. The track was center tamped and lined each day, and ballast was distributed for the second raise. When finishing up the work at night half or more of the centers were left untamped. This was done in order to have a place to start all the men to work the first thing in the morning. If a few rails beside the run-off needed relifting, it was only a short job to get started, by using four jacks.

On the second or finish lift the same general method was followed, but all tamping was done with picks. The main gang was again followed by a small gang under an assistant, who took out the light sags and kinks which were left. Another light covering of ballast was dropped over the finished surface and allowed to remain until the surfacing was done. The shoulder was dressed and finished by small gangs of 25 or 30 men. During the whole summer no regular train was stopped by the work.

The gang was composed wholly of white laborers and the camp consisted of the following: 20 bunk and dining cars, one grocery and commissary car combined, one tool car, one coal car and one foreman's car. These cars were all carefully cleaned and beds made each morning under direction of the camp watchman, who was given authority to send any one to the foreman for spitting on floors or making themselves otherwise offensive while in camp. It was also the watchman's duty to see that all men were out of the cars at 7:00 a. m., unless they were given permission by the commissary clerk to remain in camp. Two or three cars were thoroughly cleaned each week.

T. F. S.,
Roadmaster.

RAILWAY CONSTRUCTION.

Construction has been started on the Sun River branch of the Great Northern. This will be a part of a cut-off across the divide.

Contracts are to be let by the Houston & Texas Central to build from Stone City, Tex., via Caldwell to Lincoln or Giddings. There will be five steel bridges varying in length from 60 to 500 ft. each.

The Union Pacific has begun work on a 34-mile extension, it is said, of the Kearney & Black Hills, from Callaway, Neb.

Work has been resumed on the Medford-Drake extension of the Soo line. Several culvert crews have started activity

but a little distance northeast of Devil's Lake, which would indicate that the railroad management has decided to push to completion the construction of the line connecting the two routes of the Soo, with Devil's Lake at the center.

According to reports, a contract has been given to P. Welch & Co., by the Canadian Northern, for building about 165 miles of the line between Hope, B. C., on the Fraser river, and Kamloops, covering the entire Fraser river canyon. Work is under way on the section from Port Mann, B. C., on the Pacific coast east to Hope, 80 miles. The contract calls for the completion of this work within two years.

S. A. Robertson, San Benito, Tex., and associates, who are constructing a system of interurban lines to be operated by gasoline motor cars out of San Benito, have enlarged their plans. The first 40 miles of the line was recently opened for passenger and freight traffic. Arrangements have been made for constructing immediately about 60 miles additional. The St. Louis & San Francisco is said to be back of the project.

The Gulf, Florida & Alabama has grading work now under way on the first section, Chas. Merritt, Pensacola, Fla., contractor. Other sections are ready to be let. The plans call for a line from Pensacola, north via Thomasville, Ala., Linden, Demopolis and Tuscaloosa to Jasper, about 250 miles. Maximum grades will be 0.75 per cent, and maximum curvature 5 degrees. There will be steel bridges over the Alabama and Warrior rivers and a station and piers at Pensacola, Fla.

Contracts for completing the Ottawa, Ont.-Toronto line of the Canadian Northern-Ontario have been let, it is said, as follows: To McDonald & Chism, for work from Hurdman's bridge to the Rideau river, at Hogs Back; H. Cristin, from the river towards Richmond; to Contractor Bonneville for that part from the end of Cristin's division into Richmond, and to P. J. Brennan, from Richmond, west to Smiths Falls. It is expected that work on the line will be finished this year.

The Harriman, Knoxville & Eastern has work under way. The McDowell Construction Company, Knoxville, Tenn., has a contract for a section of 17.5 miles of main line and three miles of sidings. The grading work involves handling about 30,000 cu. yds. to the mile. Maximum grades eastbound will be 0.65 per cent compensated, and maximum curvature 6 deg. It is expected to have the work completed about August 1. The plans call for a line from Harriman, Tenn., east via Knoxville, thence to a point in North Carolina. Contracts were let July 3 for building a combined freight and passenger station at Harriman, Tenn. W. J. Clarke, chief engineer, Harriman, Tenn.

Personals

E. O. Reeder succeeds E. J. Pearson as chief engineer of the C., M. & P. S. Ry., with office at Seattle, and C. F. Loweth, chief engineer of the St. Paul, has also been appointed consulting engineer of the affiliated road. W. H. Penfield, formerly engineer of construction on the Puget Sound line, has been appointed assistant chief engineer of the C., M. & St. P. Ry., with office at Chicago.

H. E. Woodburn succeeds C. B. Rush as assistant engineer maintenance of way of the C., C. C. & St. L. at Wabash, Ind.

D. L. Bush has been elected president of the Davenport, Rock Island & Northwestern Ry., with office at Chicago.

N. B. Walton has been appointed assistant to the general superintendent, Grand Trunk Pacific Ry., with office at Winnipeg.

John M. Egan has been appointed superintendent of the Mississippi division, Illinois Central R. R., vice J. G. Neudorfer. His headquarters are at Water Valley, Miss.

G. B. Gunn succeeds C. F. Spencer as superintendent of construction of the Long Island, with office at Jamaica N. Y.

J. F. Murphy has been promoted to general superintendent of the Missouri Pacific System at St. Louis, Mo.

E. F. Mitchell has been appointed chief engineer of the Missouri Pacific System and John R. Stephens assistant chief engineer, both with offices at St. Louis.

Carl Stradley succeeds Wm. Ashton as chief engineer of the Oregon Short Line, with office at Salt Lake City.

R. B. M. Wilson has been appointed engineer maintenance of way of the Sonora Ry. and the Southern Pacific R. R. of Mexico, succeeding C. E. Weaver. His headquarters are at Empalme, Son., Mexico.

Major B. S. Wathen has been appointed consulting engineed of the Texas Pacific Ry., with headquarters at Dallas, Tex. C. H. Chamberlin has been appointed chief engineer, also with offices at Dallas.

A. W. Munster has been appointed engineer of tests of the New York, New Haven & Hartford, succeeding B. S. Hinckley, transferred. Mr. Munster will have offices at Boston, Mass.

John J. Pelley, roadmaster of the Illinois Central at New Orleans, La., has been transferred to Fulton, Ky., succeeding J. M. Egan, appointed superintendent. C. E. Weaver, resident engineer at New Orleans, succeeds Mr. Pelley. Shelby S. Roberts has been appointed a division engineer, with office at Chicago, succeeding E. I. Rogers, transferred to New Orleans.

F. E. Whitcomb, formerly engineer maintenance of signals, has been appointed signal engineer of the Boston & Albany, with office at Boston, Mass. The former office has been abolished.

B. Violett, formerly roadmaster at Jacksonville, Ill., has been transferred to the Beardstown division, C., B. & Q. R. R. He is succeeded at Jacksonville by J. A. Sullivan, formerly roadmaster at St. Louis, Mo.

A. B. Corthell has been appointed chief engineer of the Boston & Maine, with headquarters at Boston, Mass., succeeding J. P. Snow, resigned. Mr. Corthell also holds the position of consulting engineer of the N. Y., N. H. & H. R. R.

T. L. Dunn, chief engineer, and G. F. Black, engineer maintenance of way, of the Maine Central, have had their jurisdiction extended over the Portland Terminal Co. Offices at Portland, Me.

Phil. Carrol, division engineer of the Missouri Pacific, has been appointed engineer maintenance of way, with office at St. Louis. O. Rickert, division engineer at Atchison, Kans., has been transferred to Falls City, Neb.

A. R. Cook, formerly engineer maintenance of way of the Northern Pacific lines West of Paradise, Wash., has been appointed principal assistant engineer, with office at Tacoma, Wash. This is a new office. L. M. Perkins, formerly engineer maintenance of way of lines East of Paradise, succeeds Mr. Cook, with office at Tacoma, Wash. Andrew Gibson, formerly head of the timber department at Missoula, Mont., succeeds Mr. Cook, and will have offices at St. Paul, Minn.

David L. Robertson has been appointed assistant engineer of the N. Y. C. & H. R. R. R., office at New York, succeeding S. C. Upson.

F. G. Jonah has been appointed chief engineer of the St. Louis, Brownsville & Mexico, and the New Orleans, Texas & Mexico, with office at St. Louis, Mo. On the former road Mr. Jonah succeeds M. C Byers, transferred.

P. J. Carter has been appointed assistant engineer of the Gulf, Colorado & Santa Fe, succeeding Kenneth B. Duncan, transferred to Topeka, Kan. Mr. Carter will have offices at Galveston, Tex.

With The Manufacturers

New Literature

The Otto Gas Engine Works, Philadelphia, Pa., is sending out circulars describing and illustrating the Otto Gasoline Electric Tool Car, which, it is claimed, is an innovation in section tool cars. The circular is of attractive design and describes and illustrates the uses and construction of the car.

* * * *

The International Switch & Signal Co., 111 Purchase St., Boston, Mass., has gotten out a catalogue describing practical heating devices to keep switch and signal apparatus from clogging and freezing during winter storms. This company claims the ownership of all patents covering devices of this class. Diagrams and descriptions of the apparatus are given and illustrations are shown of the device in practical operation.

* * * *

The United States Electric Signal Co., of West Newton, Mass., has issued Bulletin No. 1, containing information pertaining to the standard type G-1 signal with semaphore attachment. The method of operation of the system, together with its mechanical and electrical features are set forth by means of photographs, descriptions and drawings.

* * * *

The Western Electric Co. is sending out a pamphlet entitled, "Our Contribution." The many cuts show the equipment which this firm has designed for telephone train dispatching systems, to meet the requirements of both steam and electric railways.

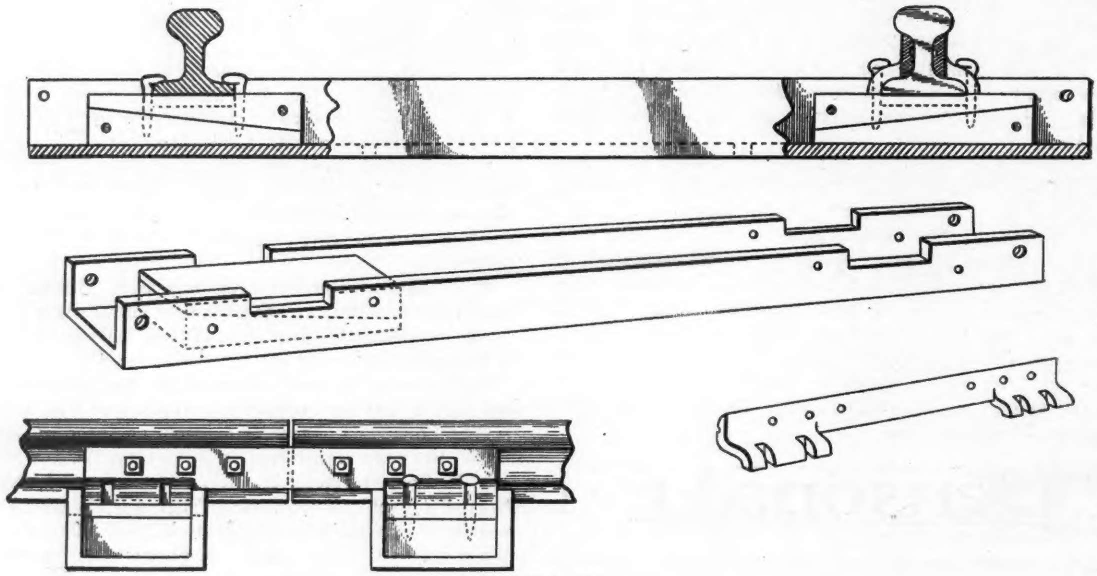
FULLARD PATENT RAILWAY TIE.

The Fullard steel railway tie, which has recently been placed on the market, is for use in tunnel or subway construction and large terminals. It is particularly adapted for these purposes as will be seen from the following description of its construction and advantages.

This device consists primarily of a railway tie comprising a base of channel metal and rail supports consisting of independent wooden blocks adjacent to the opposite ends of the base and seated within the channel.

The channel section has cut away portions at either end, and these notches or grooves are the same width as the base of the rail which is to be used. These grooves are also to be located on the tie channel so that the rails will be at exact gage when in position. This arrangement will preserve correct gage during the life of the tie.

The cushioning blocks are about one foot long, and sufficiently thick to take a good deal of wear before the rail base can cut down to or rest on the sides of the channel. The rail supporting blocks are made in two wedge-shaped sections. The rails are spiked to the wooden blocks with spikes long enough to secure a firm hold in both sections of the block. The sections of the rail supporting blocks are held from lateral motion by spikes driven into them through the sides of the channel. These features are shown in the side view at the top of the accompanying illustration. If at any time it is desired to raise the rail on a few ties only, the spikes may be withdrawn and the blocks driven toward each other until the desired height is attained. When the upper block becomes badly cut by the rail, the blocks can be interchanged, putting the worn face bottom down against the channel, and putting the unworn face of the other



Fullard Metal Tie.

block so that it takes the rail bearing. Thus the life of the wooden blocks is greatly lengthened.

A special joint splice is designed for use where these ties are to be used. The angled portion of this splice (shown above) is the same width as and projects down into the channel. The sides of this angle abut against the sides of the tie, and thus the longitudinal or creeping movement of the rails is communicated directly to the tie without cutting or wearing the joint spikes, as in an ordinary joint.

It will be observed that the cushioning rail supports form a portion of a structure having the characteristics of an integral tie, which has in addition the anti-rail-spreading feature and adjustability independently of the road bed,

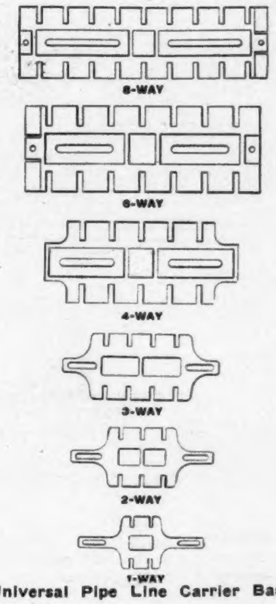
thus permitting the take up of wear which may occur upon the rail supporting cushions.

The Fullard tie is being handled by Michael E. Lynch, Bloomfield, N. J.

UNIVERSAL PIPE LINE CARRIER BASE.

The Universal Pipe Line Carrier Base, illustrated herewith, was designed as a substitute and improvement on the wooden top which has been in use for so many years.

To insure the greatest durability and strength, it is made only in malleable iron. The base is manufactured in two patterns—for ⅜-in. or ½-in. slots. These sizes provide for the carriers now in common use. The design of the base is such that two adjustments are possible, i. e., a lateral adjustment of the base on the concrete block and a second adjustment, if necessary, of the carrier stand.



Universal Pipe Line Carrier Base.

There are six sizes:—1-way, 2-way, 3-way, 4-way, 6-way and 8-way. The 6-way and 8-way sizes are lap-jointed, and when attached in combination, provide for any number of carriers.

The Universal Base is manufactured by the W. K. Kenly Company at Chicago, where a large stock in all sizes is carried to insure prompt shipments.

PROTECTIVE PAINT.

In the manufacture of Indian Brand paints for protection against corrosion, gases, and acids, a new patented substitute for linseed oil is used. It is claimed that the new oil forms a protection against corrosive action which is practically perfect, and its application is as easy and simple as is that of the old style paints. Tests have been conducted by Mr. Mueller (company chemist) of the severest nature and show the resistance of the paint to both mechanical and chemical destructive agents. The pigments are so well protected by the oil that the delicate shades of red and green show no change when subjected to the action of the strongest acids and alkalies.

Boiling hydrochloric, sulphuric and nitric acids placed on tin protected by a coat of the paint have no effect. Oxygen produced by electrolysis, especially corrosive in the nascent state and which attacks and destroys with rapidity metals exposed to its action, does not affect those protected by a thin coat of this paint.

This paint comes in a variety of colors, and is manufactured by Pendleton & Co., Front and Thompson Sts., Stapleton (S. I.) N. Y.

INDUSTRIAL NOTES.

The John F. Allen Company, builders of the Allen riveting machines, and one of the representative manufacturing concerns of upper New York City, are now represented in San Francisco, Cal., Oregon and Washington, by the Berger & Carter Company, San Francisco, Cal., who carry a full stock of the Allen riveters for immediate delivery on the Pacific Coast. This will eliminate any delay which has been necessary heretofore in filling orders of Western buyers.

The Hale & Kilburn Company, New York, has moved its Chicago office from the Fisher building to the McCormick building.

The American Car & Foundry Co. plans to build a one-story steel hammer and forge shop at 2513 South Wood street, Chicago.

The Western Electric Co. has received an order from the Oregon-Washington Railroad & Navigation Co. for telephone train dispatching equipment for a circuit from Portland, Ore., to The Dalles, Ore., a distance of 90 miles. This circuit will be equipped with seventeen stations.

W. G. Willcoxson has been made sales manager of the Grip Nut Company at Chicago, with headquarters in the Old Colony building.

The Bontempi Rust-Proofing Company, 111 Broadway, New York, has leased a plot of land 70x142 ft. in Bridgeport, Conn., on which the company will erect furnaces for commercial purposes. The contract for constructing the furnaces has been let to the W. S. Rockwell Company, 50 Church street, New York.

The Homestead Valve Manufacturing Co. reports that Chas. B. Scott & Co., of 119 Franklin avenue, has been appointed agent in Scranton and vicinity. This company will carry a stock of Homestead valves and will be ready to supply the trade in this city and vicinity at all times.

McClernan & Co., Chicago, dealers in iron and steel, moved their offices from the Monadnock building to the Peoples Gas building.

The General Electric Co. has received the following orders for railway equipments and apparatus: Thirty partial 4-motor car equipments with K-35 controllers from Louisville Railway Co., Louisville, Ky.; 20 GE-80 2-motor car equipments with K-10 controllers from the Waldemar Construction Co., for the Erie & Suburban Railway; three 1,000-kva. transformers, one 1,000-kw. rotary converter, three 350-kva. transformers and a switchboard from the Syracuse Rapid Transit Co., Syracuse, N. Y.

The Westinghouse Electric & Manufacturing Co., East Pittsburg, Pa., has received the following orders for railway motors: Morris County Traction Company, Morristown, N. J., ten quadruple equipments of No. 101-B-2 railway motors for type K-28-B control; Marshall Traction Co., Marshall, Texas, two double equipments of No. 307 interpole motors with type K-10 control; Walter Brothers & Co., Rio de Janeiro, Brazil, 15 double equipments of No. 101-G motors with type K-10-A control.

The United States Electric Co., New York and Chicago, has received an order from the Bessemer & Lake Erie Railroad Co. for 36 Gill selector equipments, bells to be rung by main line battery; also the Gill calling keys and the telephone equipment necessary for the installation of the circuit. The same company is also furnishing for the Oregon-Washington Railway & Navigation Co. 25 No. 502 Gill main line selector outfits, including the United States Electric Co.'s universal resistance and calling keys to operate the circuit.

Recent Engineering and Maintenance of Way Patents

DEVICE FOR CHECKING CREEP OF RAILWAY RAILS.

994,795—Hiram H. Sponenburg, Gurnee, Ill., assignor to Otto R. Barnett, Chicago, Ill.

This device consists of a clamp which is made up of a spring and a rail engaging lug. The spring is strained longitudinally when the device is in operative position on the rail. An abutment protrudes downwardly to rest against the side of the tie.

METAL RAILWAY TIE.

995,386—John W. Stephenson, Toledo, O., assignor to the National Malleable Castings Co., Cleveland, O.

This metal railway tie comprises a top portion and a zig-zag web depending from the top portion, the web being of decreasing depth from the center toward the end of the tie.

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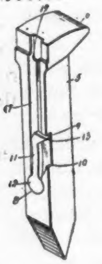

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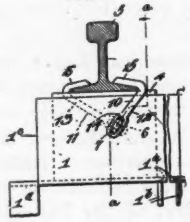

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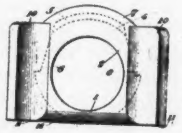

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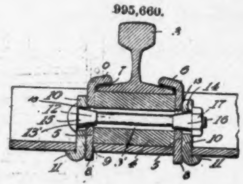
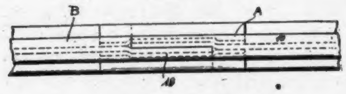
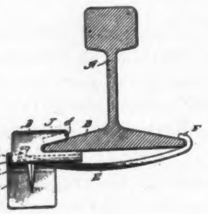


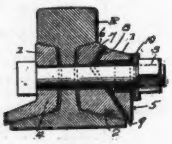
995,850.



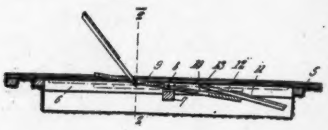
994,795.



995,842



995,943



RAIL ANCHOR.

995,488—John M. Scott, Racine, Wis., assignor to Otto R. Barnett, Chicago, Ill.

This rail anchor has a rail engaging jaw provided with a shoulder for abutting against the tie and a strap provided with jaws at each end. The jaw at one end of the strap engages the part of the device provided with the tie shoulder. The opposite jaw engages the base of the rail.

CONCRETE POLE.

994,912—Elbert M. Elliott, Lincoln, Neb.

This patent relates to a concrete pole having a number of rectangular anchoring members embedded therein and disposed one above the other in spaced relation. The anchoring members are provided with flat upper and lower faces, and at one corner thereof only with a laterally extending arm, the free end of which is provided with a head disposed at right angles to the length of the arm and adapted to bear against the adjacent exterior face of the pole, there being a socket formed in each head for the reception of a removable step.

RAILWAY TIE.

995,541—Orson N. Kelley, Salt Lake City, Utah.

This tie is a combination of a hollow body, containing a block bolted to the shell. Rail securing clamps are fastened to the bolt. The bolt has a wedge shaped head to engage the opening of one of the securing clamps. A wedge shaped adjustable sleeve engages the opposite rail clamp.

RAILROAD SPIKE.

995,503—Thomas Wakefield, Taylor, Ariz.

This spike has a vertical slot in one face terminating in a circular shaped recess, and a dog having a circular shaped end correspondingly shaped to the recess and detachably fitted into the slot and recess. The spike is provided with an opening communicating with the slot through which the dog is adapted to move. A wedge shaped pin in the slot operates upon the dog for moving it in locked position. The spike is formed with a shoulder near its upper end and the wedge shaped pin is formed with a shoulder adapted to be locked to the shoulder of the spike.

CONCRETE CULVERT.

995,659—Robert J. Burns, Hewitt, Okla.

This is a tubular culvert traversed from end to end by a cylindrical drain opening, the upper half of the culvert being of a greater thickness than the lower half and having two opposite flat faces each ending in a narrow lengthwise running ledge. The culvert at each upper end is slightly enlarged and ends in a skirting flange. Two retaining wings obliquely extend from each end of the culvert, the bottom edge of the wings being in a common plane extending tangentially to the bottom part of said culvert.

FASTENING FOR RAILWAY RAILS.

995,660—Arthur C. Candland, Provo, Utah.

A fastening device composed of two rail base engaging clamps extending through an aperture to the bottom of the tie. There are two clamps which engage the bottoms of the tie, and blocks between the clamps, as shown. A bolt holds the parts together and is provided with conical surfaces which wedge the different parts firmly together when the bolt is tightened.

INSULATED RAIL JOINT.

995,842—Christian Buck, Gallitzin, Pa., assignor to the Rail Joint Co., New York.

This insulated rail joint comprises splice bars and filler members abutting the rail and in contact with the under side of its head. These members have projections extending therefrom and insulating members interposed between them and the splice bars, the area of the projections exposed to the insulating members being of a greater area than the area of the under side of the rail head.

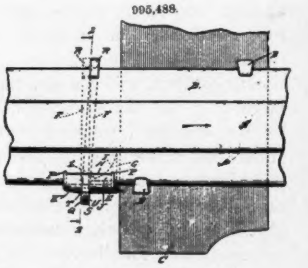
RAIL JOINT.

995,850—Albert T. Eickmeyer, Potlatch, Idaho.

A rail joint comprising a pair of rails having the adjacent ends of their webs offset in opposite directions and the respective balls and bases provided with oppositely disposed cut-away portions. Splice plates are disposed on each side of the rails and overlap the same, each of which is provided with a central offset portion in which the offset portion of the adjacent rail web is received. Bolts pass through the splice plates and rails, to secure them together.

994,912.

995,488.



995,386